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Kousaridas et al.

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(45) **Date of Patent: *Dec. 26, 2023**

(54) **TECHNIQUES FOR QUALITY OF SERVICE NEGOTIATION**

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This patent is subject to a terminal disclaimer.

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(63) Continuation of application No. 16/859,626, filed on Apr. 27, 2020, now Pat. No. 11,284,289, which is a (Continued)

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H04W 28/02 (2009.01)
H04W 76/27 (2018.01)
(Continued)

(52) **U.S. Cl.**
CPC ... ***H04W 28/0268*** (2013.01); ***H04W 36/0044*** (2013.01); ***H04W 68/005*** (2013.01); ***H04W 72/1263*** (2013.01); ***H04W 76/27*** (2018.02)

(58) **Field of Classification Search**
CPC H04W 4/40; H04W 4/44; H04W 4/46; H04W 28/00; H04W 28/16; H04W 28/24;
(Continued)

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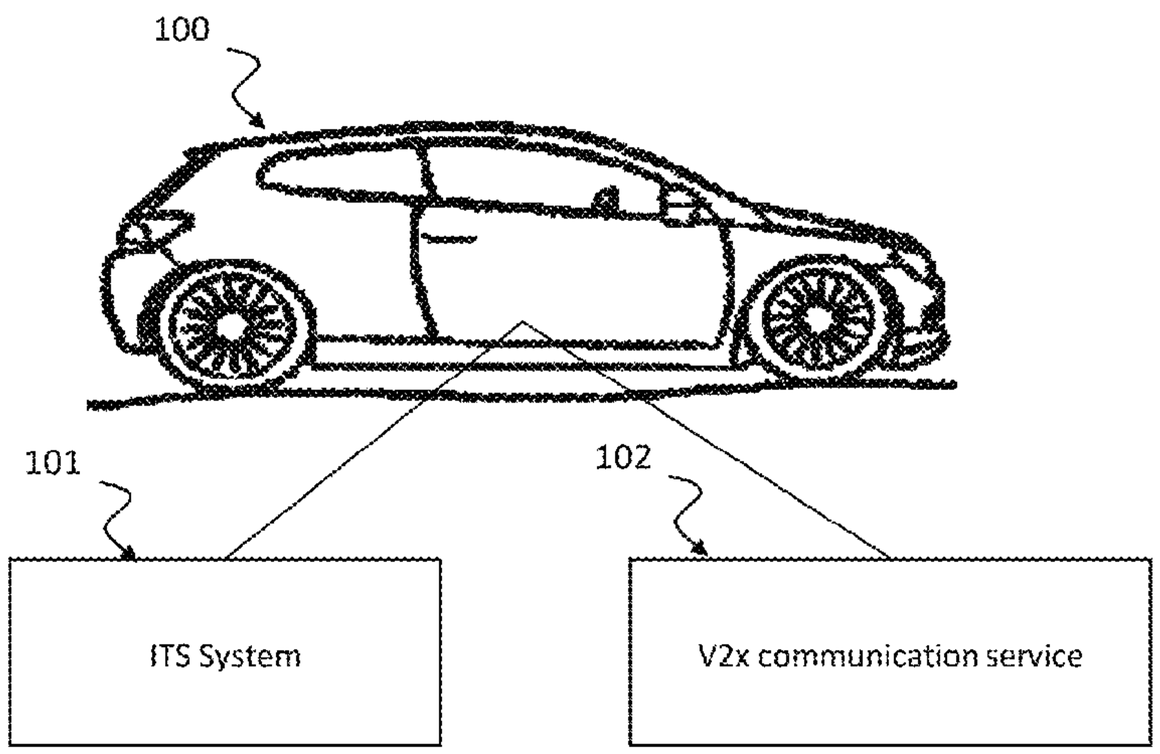
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(Continued)

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(57) **ABSTRACT**

The disclosure relates to a mobile device, in particular a vehicle, or an application server, wherein the mobile device or the application server comprise: a processor, configured to: receive a notification from a network entity, in particular a base station, wherein the notification comprises information about available Quality of Service, QoS, and transmit a confirmation message to the network entity informing the network entity about an acceptance of the notified QoS. The disclosure further relates to a network entity, comprising: a network entity controller, configured to: transmit a notification to a mobile device, in particular a vehicle, or an application server, wherein the notification comprises information about available Quality of Service, QoS, and receive a confirmation message from the mobile device or the application server informing about an acceptance of the notified QoS.

20 Claims, 16 Drawing Sheets



Related U.S. Application Data

continuation of application No. PCT/EP2017/077465, filed on Oct. 26, 2017.

(51) **Int. Cl.**
H04W 36/00 (2009.01)
H04W 68/00 (2009.01)
H04W 72/1263 (2023.01)

(58) **Field of Classification Search**
CPC H04W 28/0268; H04W 36/0044; H04W 68/005; H04W 72/1263; H04W 76/27
See application file for complete search history.

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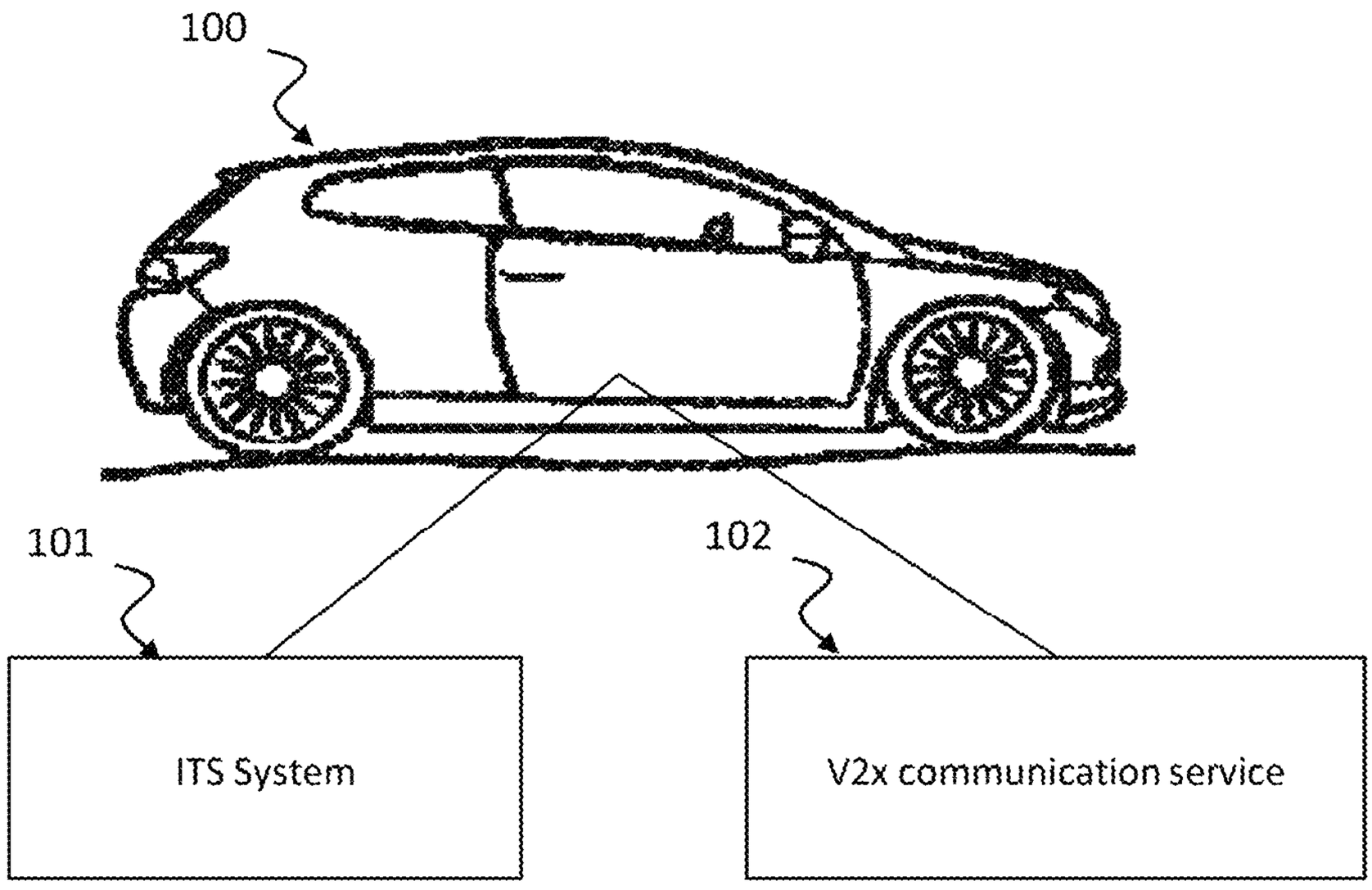
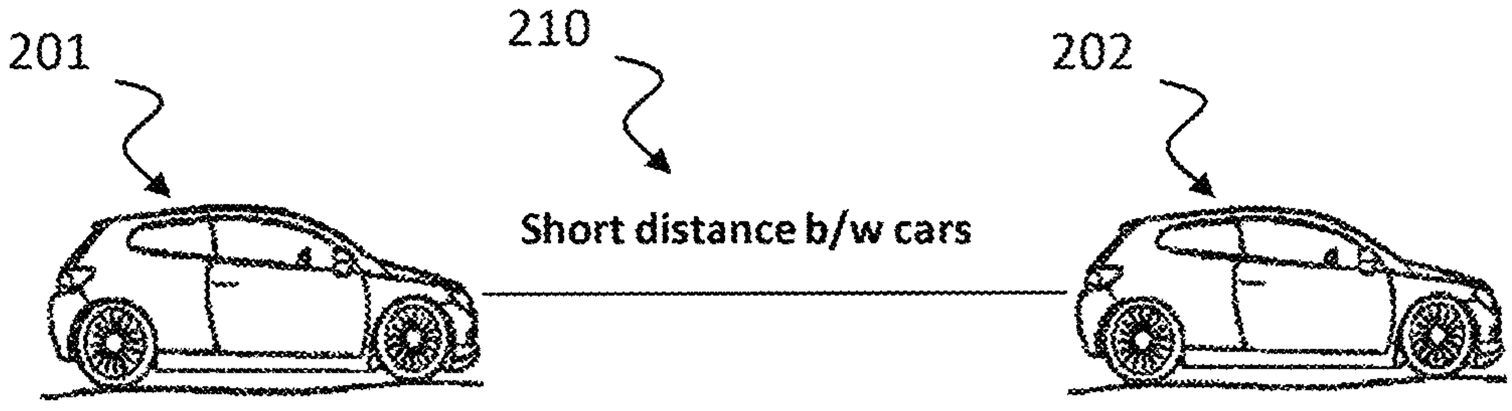


Fig. 1


201
210
202
Short distance b/w cars

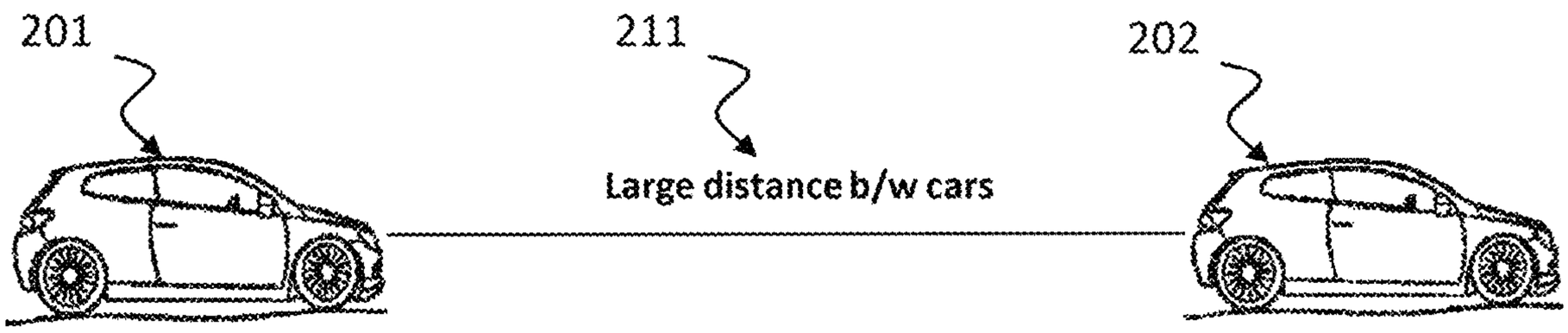

201
211
202
Large distance b/w cars

Fig. 2

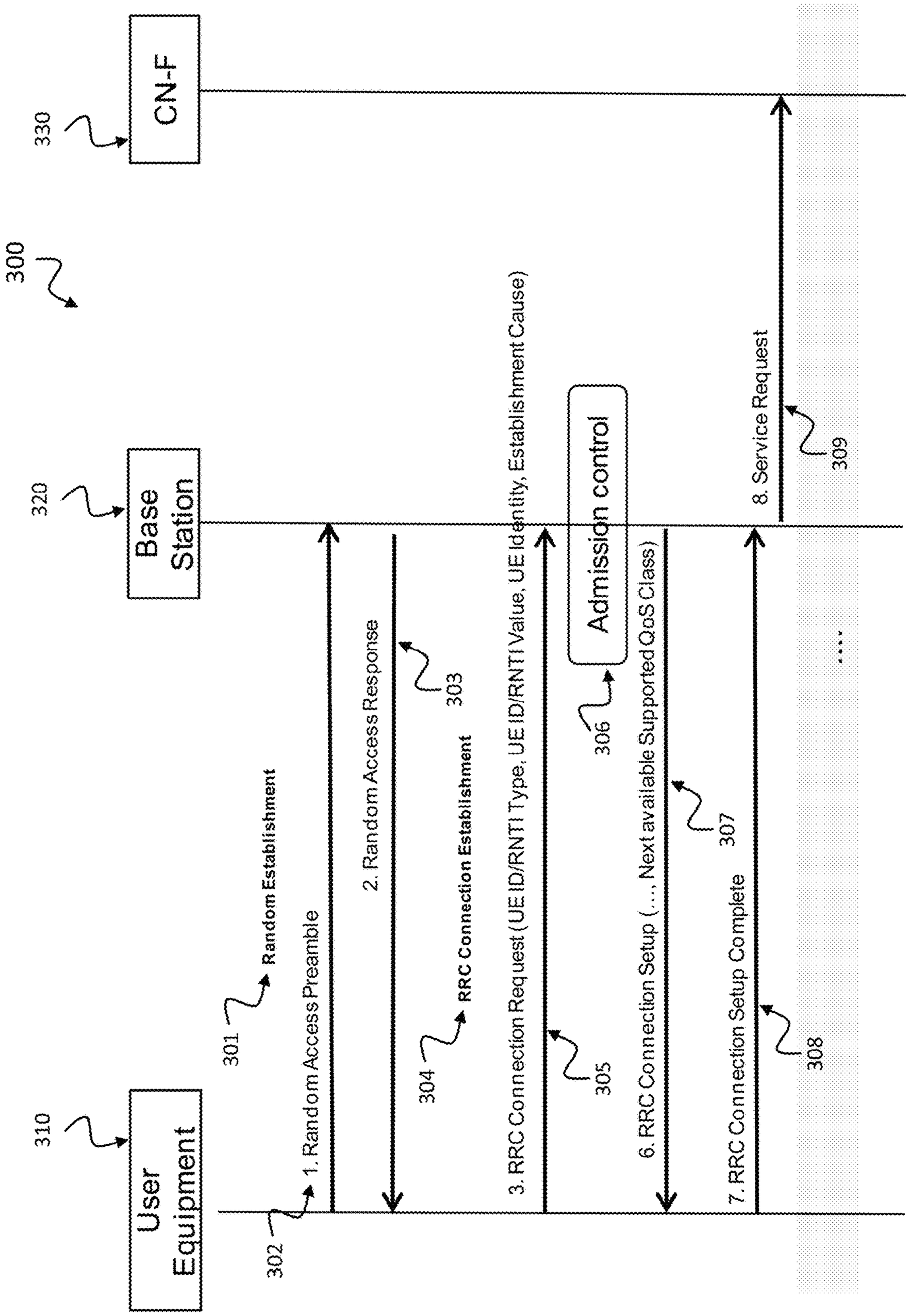

300
User Equipment
310
Base Station
320
CN-F
330
1. Random Access Preamble
302
Random Establishment
301
2. Random Access Response
303
RRC Connection Establishment
304
3. RRC Connection Request (UE ID/RNTI Type, UE ID/RNTI Value, UE Identity, Establishment Cause)
305
Admission control
306
6. RRC Connection Setup (..., Next available Supported QoS Class)
307
7. RRC Connection Setup Complete
308
8. Service Request
309
....

Fig. 3

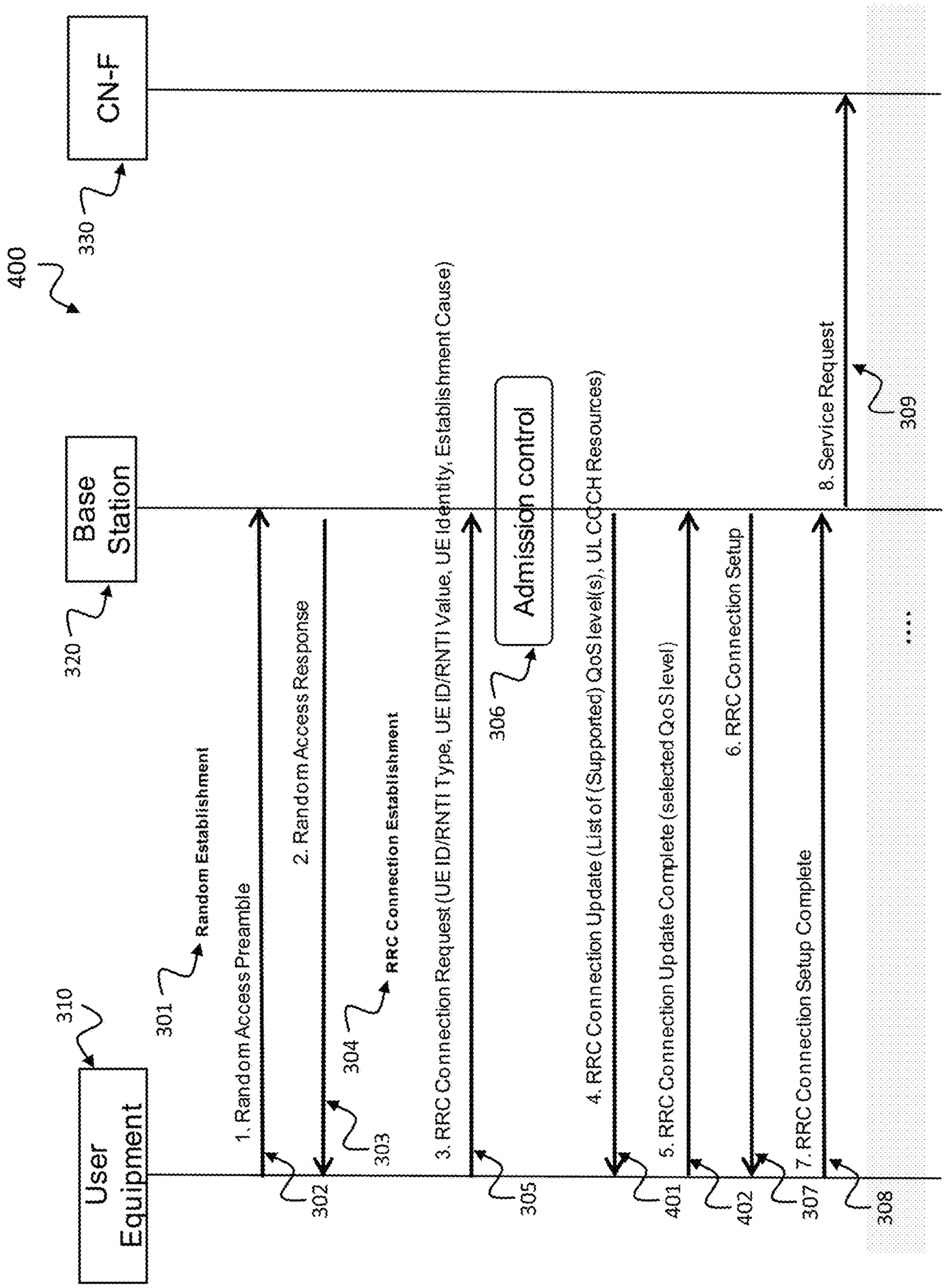

400
User Equipment
310
Base Station
320
CN-F
330
Random Access Procedure
Random Access Preamble
301
1. Random Access Preamble
2. Random Access Response
302
RRC Connection Establishment
RRC Connection Request
304
303
3. RRC Connection Request (UE ID/RNTI Type, UE ID/RNTI Value, UE Identity, Establishment Cause)
Admission control
306
305
4. RRC Connection Update (List of (Supported) QoS level(s), UL CQICH Resources)
401
5. RRC Connection Update Complete (selected QoS level)
402
6. RRC Connection Setup
307
7. RRC Connection Setup Complete
308
8. Service Request
309
....

Fig. 4

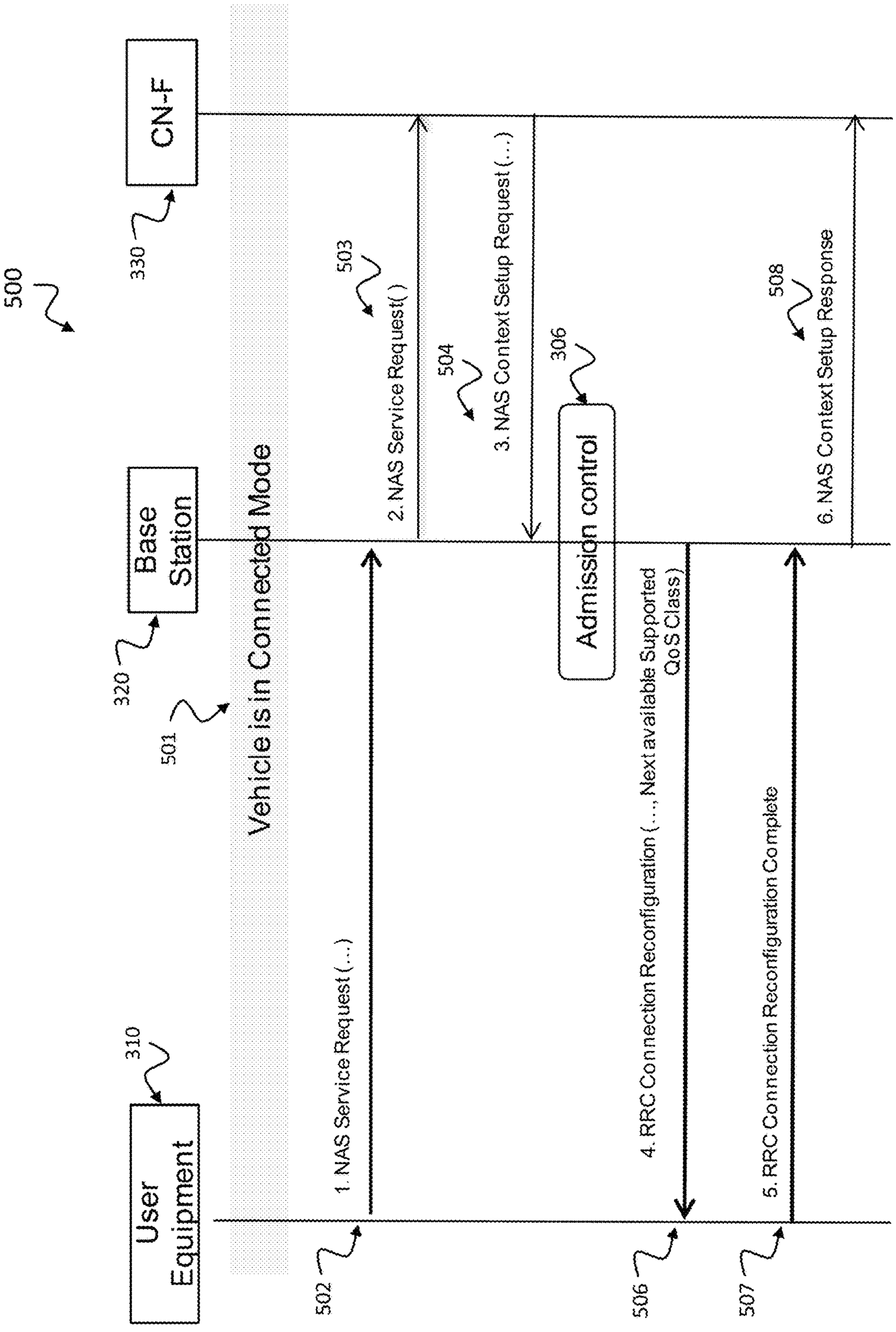

500
User Equipment
310
Base Station
320
CN-F
330
Vehicle is in Connected Mode
501
1. NAS Service Request (...)
502
2. NAS Service Request ( )
503
3. NAS Context Setup Request (...)
504
Admission control
306
4. RRC Connection Reconfiguration (..., Next available Supported QoS Class)
506
5. RRC Connection Reconfiguration Complete
507
6. NAS Context Setup Response
508

Fig. 5

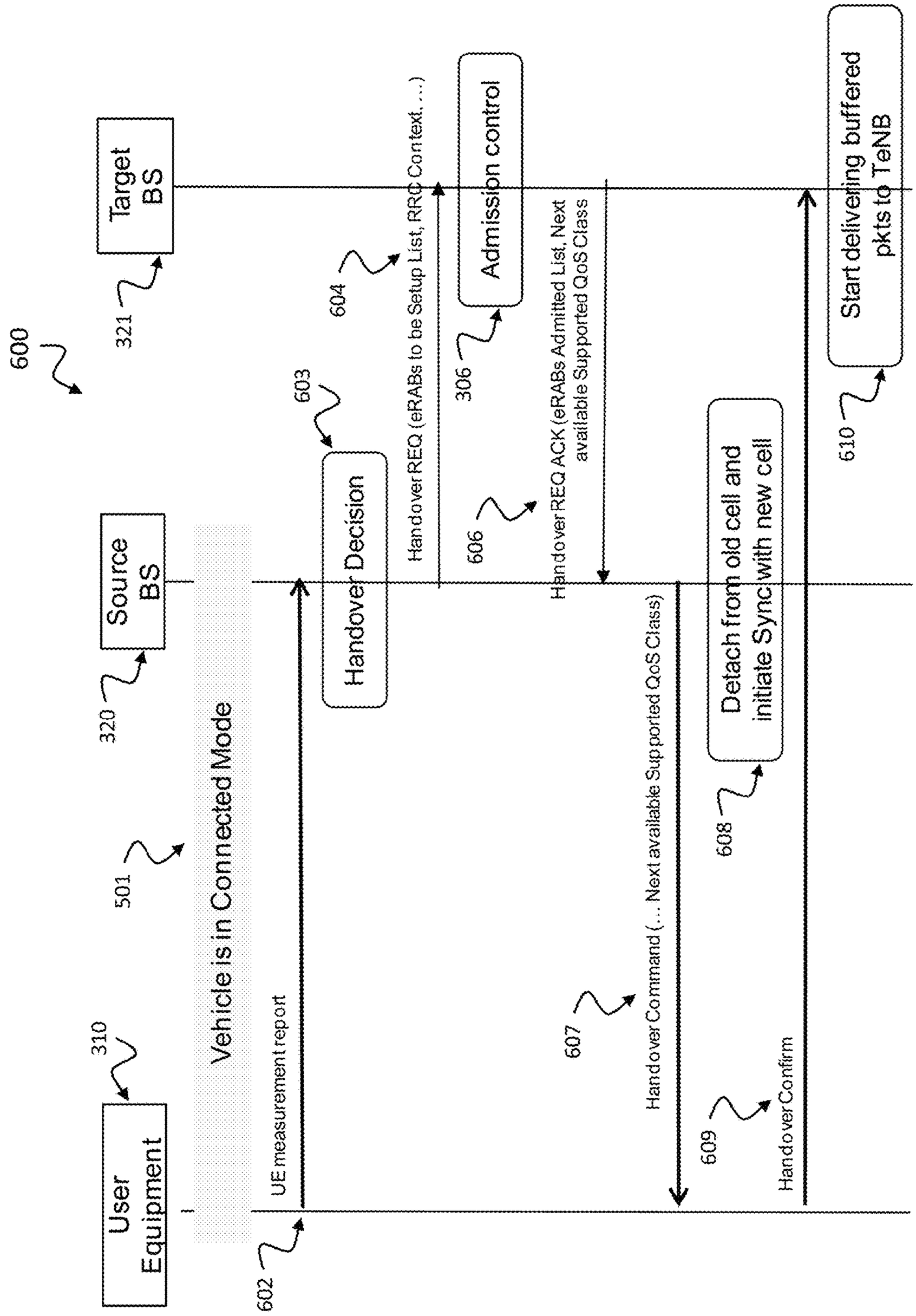

600
User Equipment
310
Source BS
320
Target BS
321
501
Vehicle is in Connected Mode
602
UE measurement report
603
Handover Decision
604
Handover REQ (eRABs to be Setup List, RRC Context, ...)
306
Admission control
606
Handover REQ ACK (eRABs Admitted List, Next available Supported QoS Class
607
Handover Command (... Next available Supported QoS Class)
608
Detach from old cell and initiate Sync with new cell
609
Handover Confirm
610
Start delivering buffered pkts to TeNB

Fig. 6

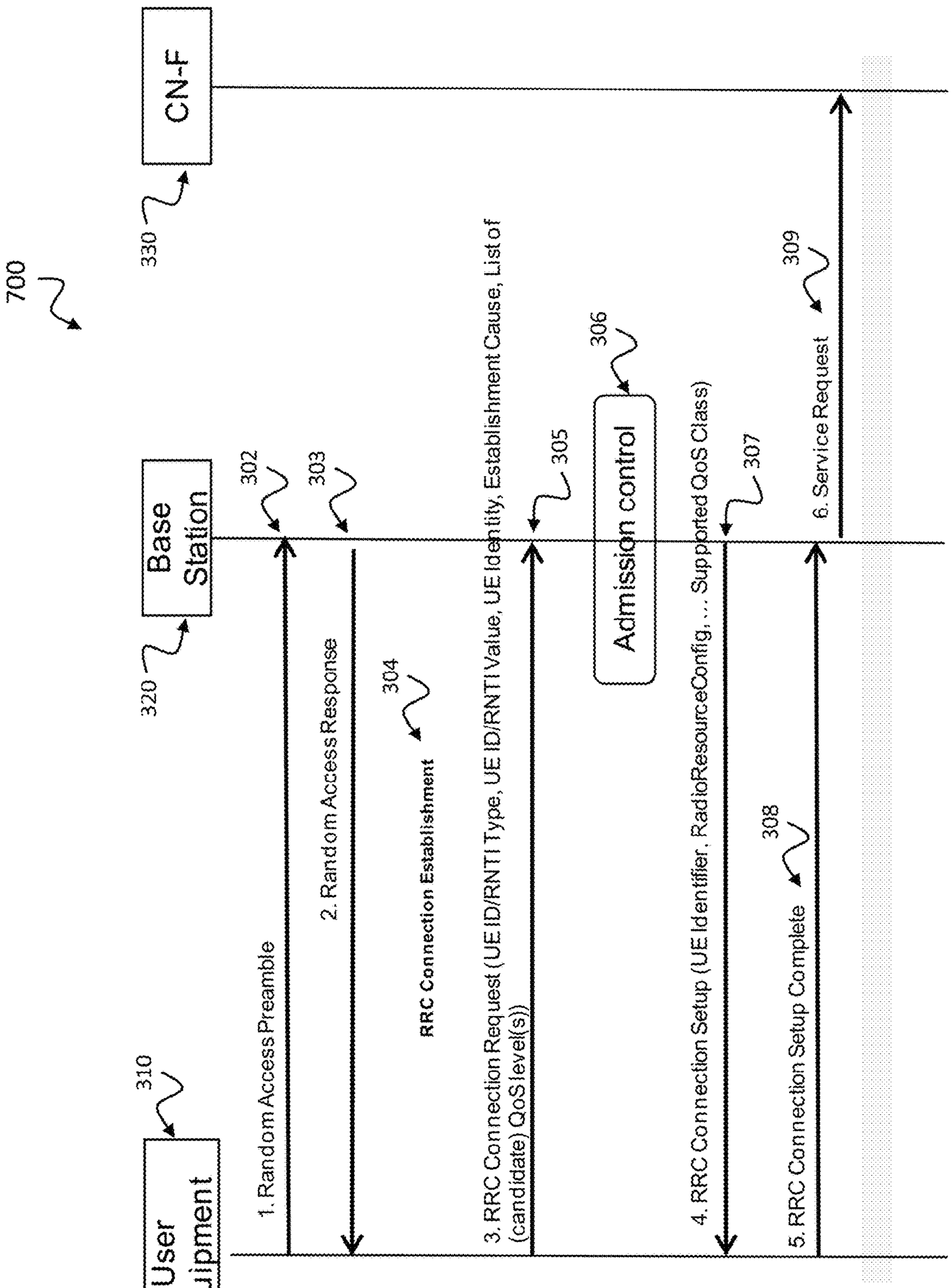

700
CN-F
330
Base Station
320
User Equipment
310
302
303
304
305
306
307
308
309
2. Random Access Response
RRC Connection Establishment
3. RRC Connection Request (UE ID/RNTI Value, UE ID/RNTI Type, UE Identity, Establishment Cause, List of (candidate) QoS level(s))
Admission control
4. RRC Connection Setup (UE Identifier, RadioResourceConfig, ... Supported QoS Class)
5. RRC Connection Setup Complete
6. Service Request

Fig. 7

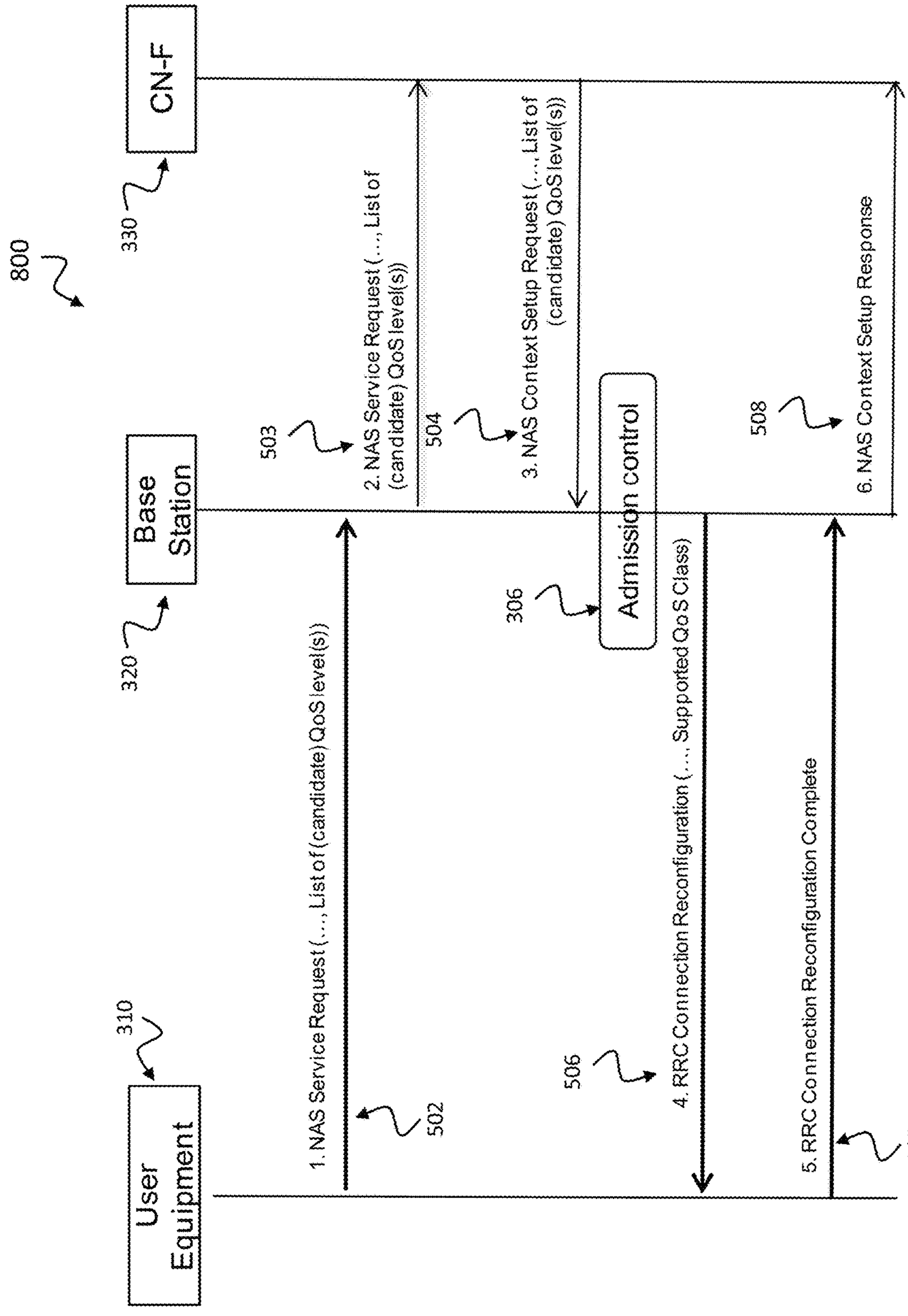

800
330
CN-F
320
Base Station
310
User Equipment
1. NAS Service Request (..., List of (candidate) QoS level(s))
502
503
2. NAS Service Request (..., List of (candidate) QoS level(s))
504
3. NAS Context Setup Request (..., List of (candidate) QoS level(s))
306
Admission control
506
4. RRC Connection Reconfiguration (..., Supported QoS Class)
5. RRC Connection Reconfiguration Complete
507
508
6. NAS Context Setup Response

Fig. 8

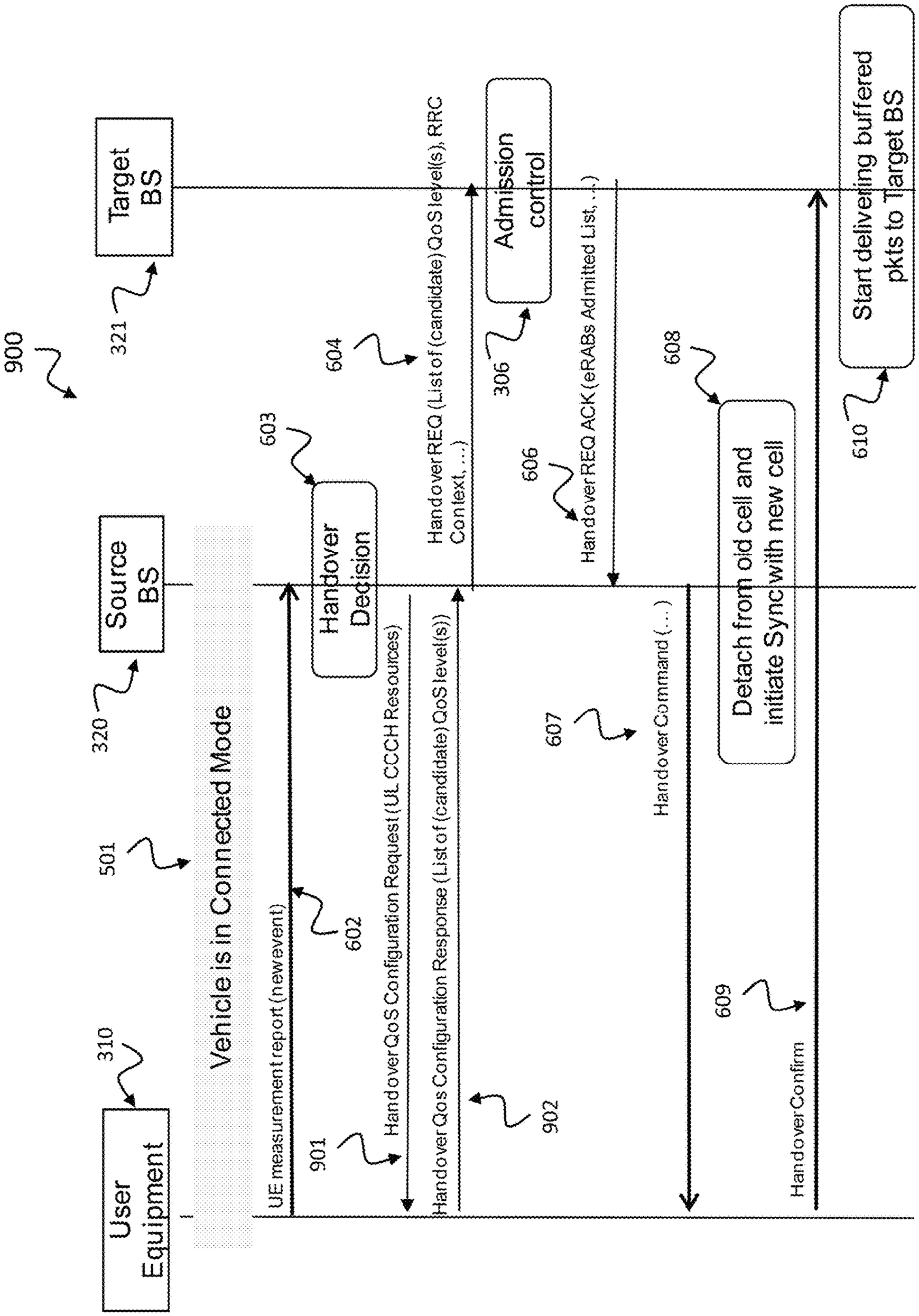

User Equipment
Source BS
Target BS
Vehicle is in Connected Mode
UE measurement report (new event)
Handover QoS Configuration Request (UL CCCH Resources)
Handover QoS Configuration Response (List of (candidate) QoS level(s))
Handover QoS Configuration Request (List of (candidate) QoS level(s), RRC Context, ...)
Handover REQ ACK (eRABs Admitted List, ...)
Handover Command (...)
Handover Confirm
Handover Decision
Admission control
Detach from old cell and initiate Sync with new cell
Start delivering buffered pkts to Target BS
310
320
321
501
602
603
604
306
606
607
608
609
610
901
902

Fig. 9

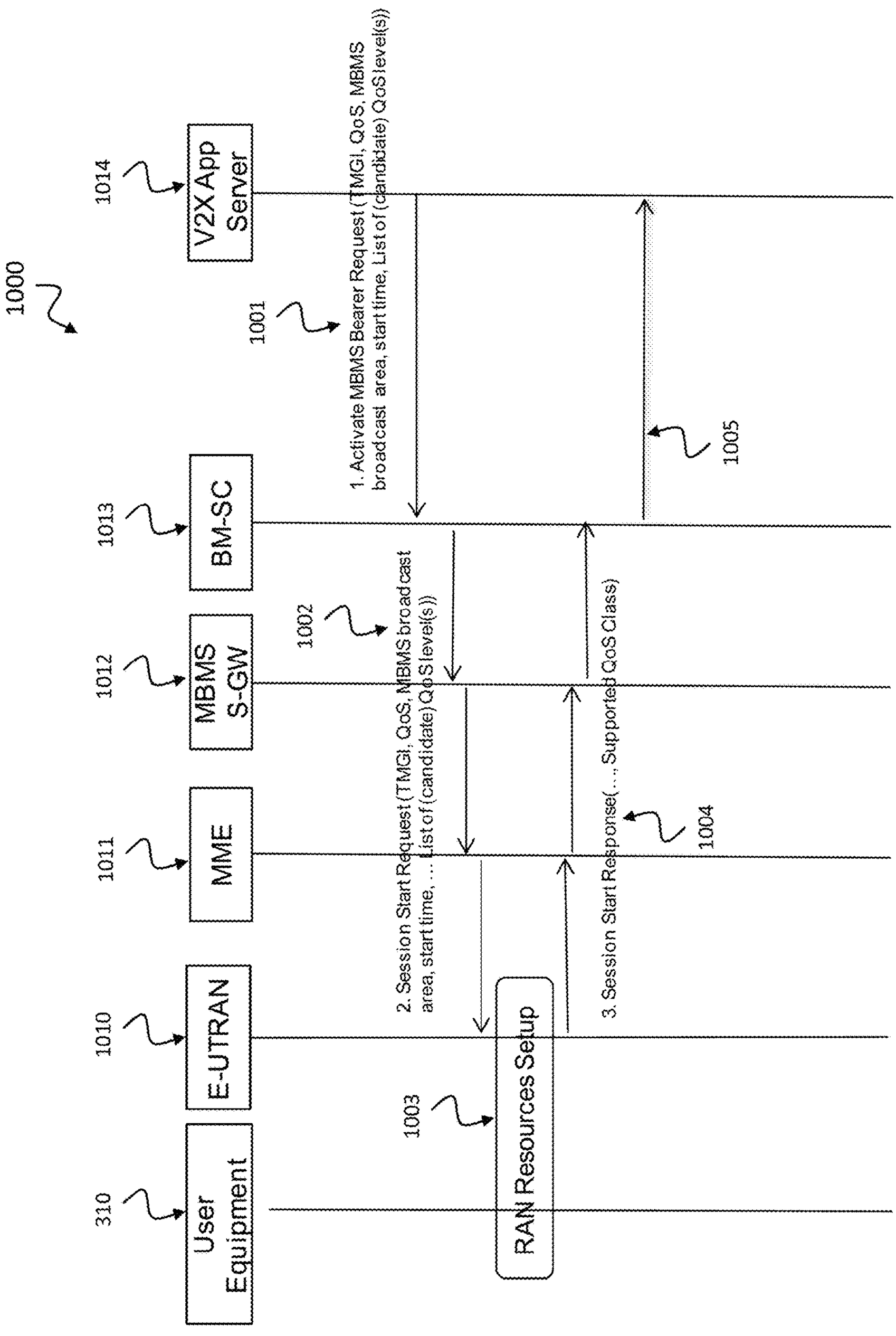

1000
1014
V2X App Server
1001
1. Activate MBMS Bearer Request (TMGI, QoS, MBMS broadcast area, start time, List of (candidate) QoS level(s))
1011
MME
1012
MBMS S-GW
1013
BM-SC
1002
2. Session Start Request (TMGI, QoS, MBMS broadcast area, start time, ... List of (candidate) QoS level(s))
1004
3. Session Start Response(..., Supported QoS Class)
1005
1010
E-UTRAN
1003
RAN Resources Setup
310
User Equipment

Fig. 10

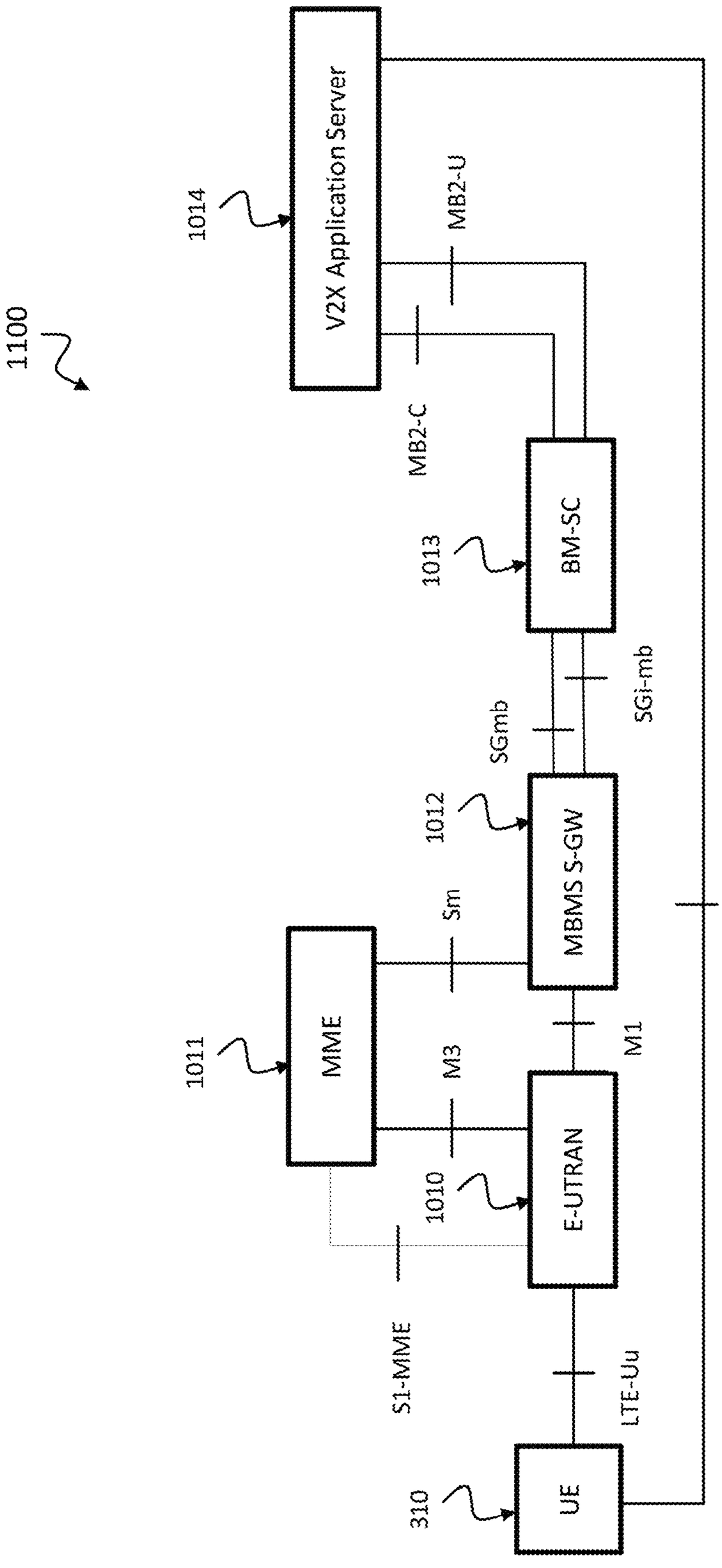

1100
1014
V2X Application Server
MB2-U
MB2-C
1013
BM-SC
SGmb
SGi-mb
1012
MBMS S-GW
Sm
V1
1011
MME
M3
M1
1010
E-UTRAN
S1-MME
LTE-Uu
310
UE

Fig. 11

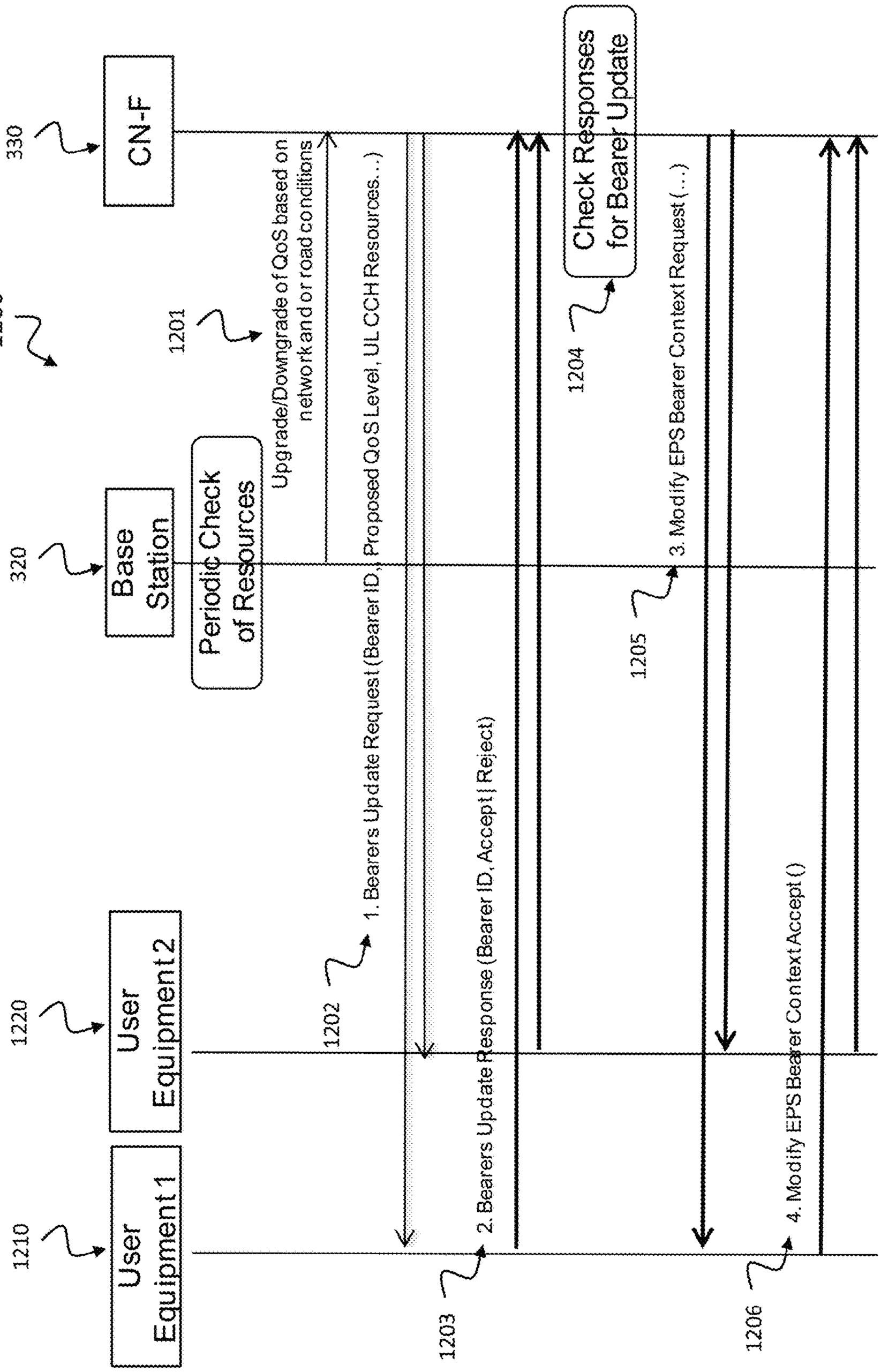

1200
320
Base Station
330
CN-F
1201
Periodic Check of Resources
Upgrade/Downgrade of QoS based on network and or road conditions
1. Bearers Update Request (Bearer ID, Proposed QoS Level, UL CCH Resources...)
2. Bearers Update Response (Bearer ID, Accept | Reject)
1202
1203
1204
Check Responses for Bearer Update
3. Modify EPS Bearer Context Request (...)
1205
4. Modify EPS Bearer Context Accept ()
1206
1210
User Equipment 1
1220
User Equipment 2

Fig. 12

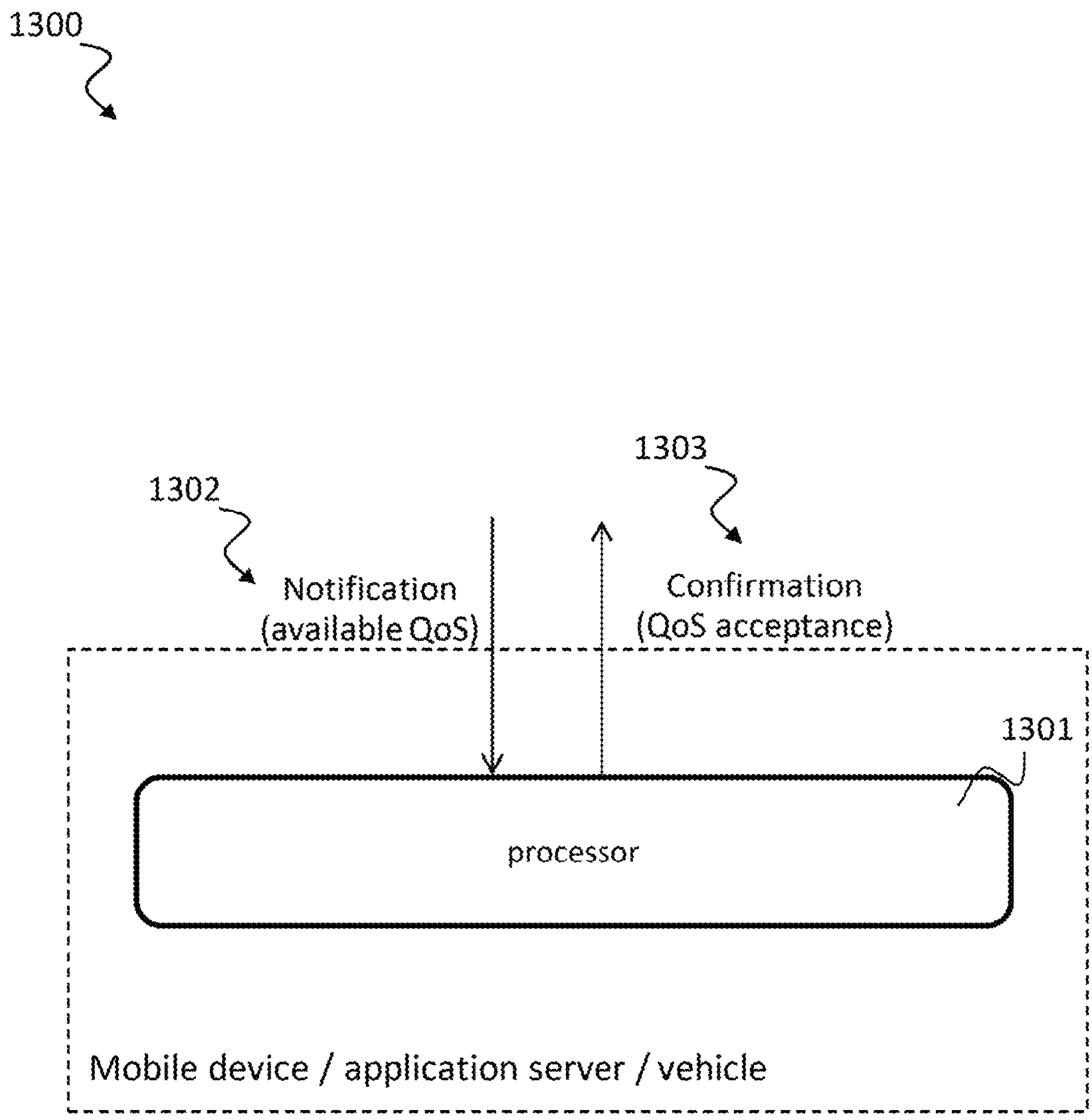

1300
1303
1302
Notification
(available QoS)
Confirmation
(QoS acceptance)
1301
processor
Mobile device / application server / vehicle

Fig. 13

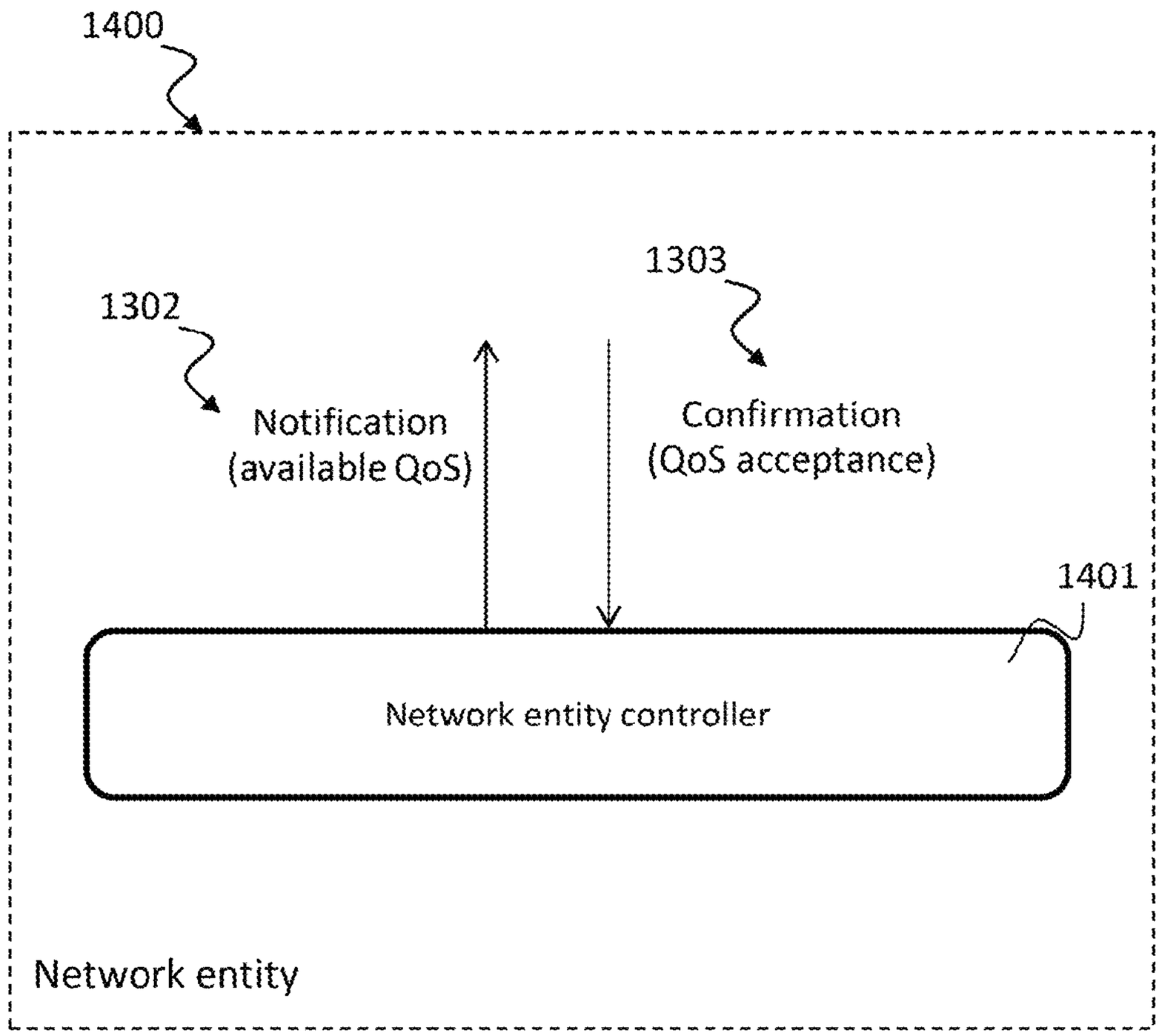

1400
1303
1302
Notification
(available QoS)
Confirmation
(QoS acceptance)
1401
Network entity controller
Network entity

Fig. 14

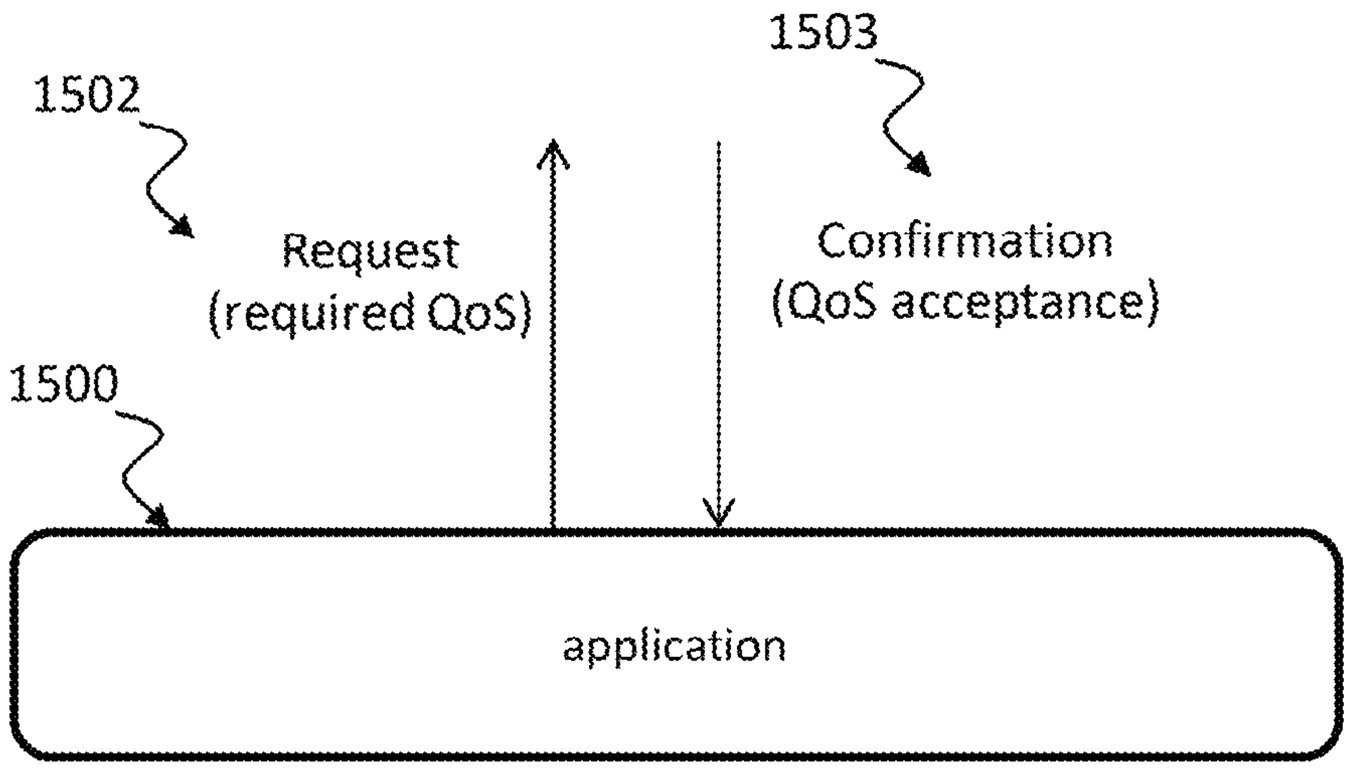

1503
1502
Request
(required QoS)
Confirmation
(QoS acceptance)
1500
application

Fig. 15

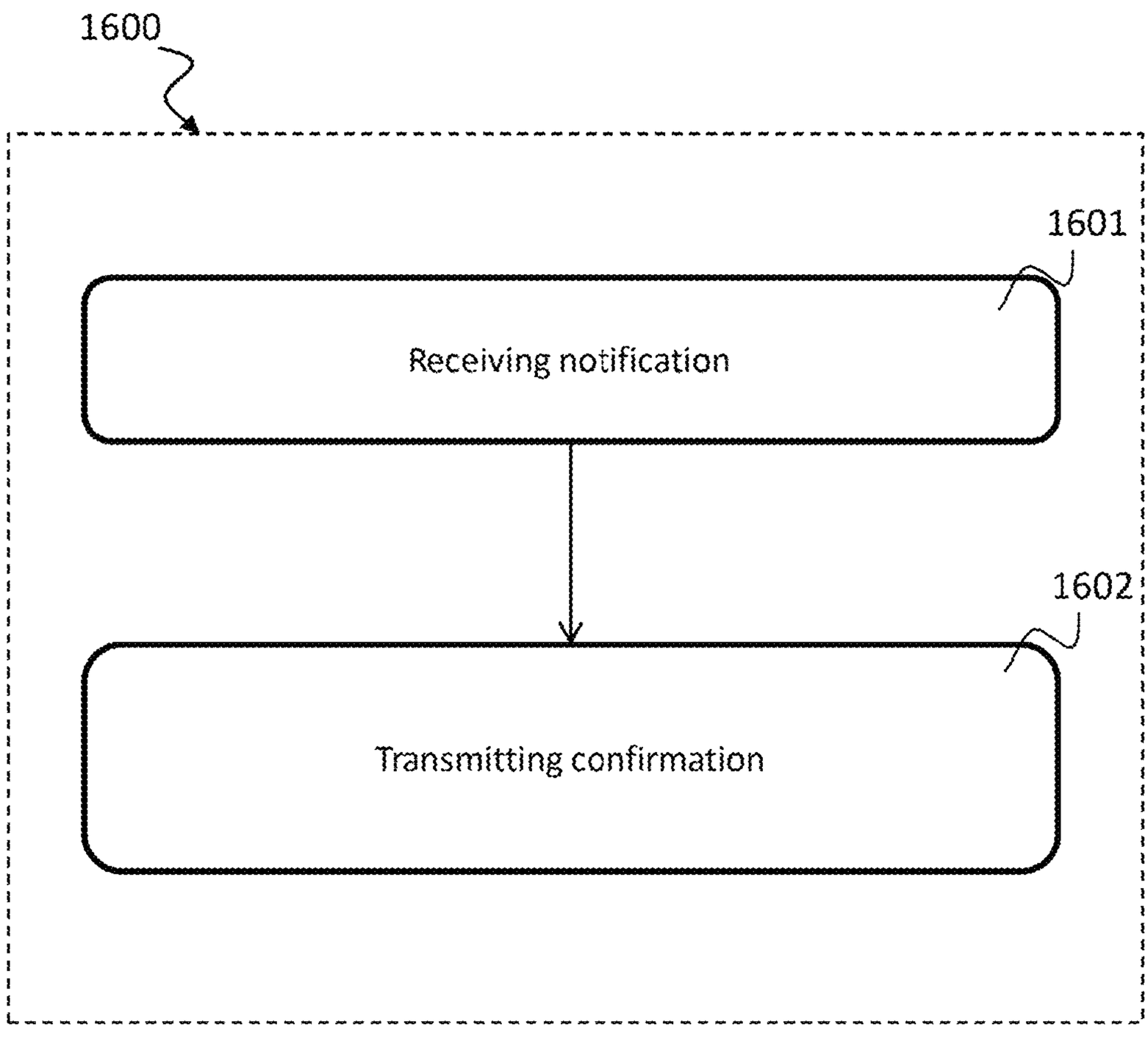

1600
1601
Receiving notification
1602
Transmitting confirmation

Fig. 16

TECHNIQUES FOR QUALITY OF SERVICE NEGOTIATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 16/859,626, filed on Apr. 27, 2020, now U.S. Pat. No. 11,284,289, which is a continuation of International Application No. PCT/EP2017/077465, filed on Oct. 26, 2017. All of the afore-mentioned patent applications are hereby incorporated by reference in their entireties.

TECHNICAL FIELD

The present disclosure relates to techniques for Quality of Service (QoS) negotiation. In particular, the disclosure relates to a mobile device, e.g. a vehicle, or an application server negotiating the QoS with a network entity, to a network entity negotiating the QoS with a mobile device or an application server and to an application for the mobile device or the application server negotiating the QoS. The disclosure further relates to a method for negotiating a QoS.

BACKGROUND

In mobile communications, use cases related to vehicle-to-anything (V2X) (e.g. platooning, advanced driving, cooperative perception) can be implemented using different QoS classes (or degrees of Key Performance Indicators, KPIs—e.g., latency, reliability levels . . .), as it is presented in 3GPP TS 22.186 V15.0.0: Service requirements for enhanced V2X scenarios (Release 15), March 2017. The different QoS classes will affect the (self-) driving behavior (e.g., speed of vehicles, distance among vehicles).

The network and vehicles/UEs can setup and dynamically modify the QoS bearers in a cooperative manner, considering network conditions and impact on driving behavior. For instance, a platooning application can modify the distance among platoon vehicles according to the QoS that the network can support for the communication among the members of the platoon at the specific period of time. The higher the QoS that the network can provide the denser the platoon can be (i.e., shorter distance among the vehicles that form the platoon), as shown in FIG. **2**.

However the existing schemes for determining QoS classes between UEs and the network during bearers' establishment (or bearers' update) are slow and not efficient. In addition, there is no early notification scheme from the network to the UEs about QoS changes that can consequently facilitate the "early" modification of the (V2X) application layer, due to the change of network conditions.

SUMMARY

It is the object of the invention to provide efficient techniques for providing faster and safe communication between mobile devices such as vehicles.

In particular it is the object of the invention to enable a faster "negotiation" between a UE (or a group of them) and the Radio Access Network (RAN (BS) or Core Network (CN) entities (e.g., MME in LTE, AMF in 5G)) to establish vehicle-to-vehicle (V2V) radio bearers, whenever the Admission Control is triggered during scenarios such as Connection establishment, New Service/bearer establishment, Handover etc.

This object is achieved by the features of the independent claims. Further implementation forms are apparent from the dependent claims, the description and the figures.

The disclosure presents solutions to this problem. These solutions reduce the bearer establishment time and provide flexibility to both network and V2X application sides. In particular, solutions to this problem provide an early notification of a UE (or a group of them) for the modification of V2V radio bearers that are already established and used by V2V applications. This will increase the reliability of the system, allowing the V2X application to be notified (feedback) early enough for a modification of a bearer. The latter will allow the V2X application in the vehicles to modify their driving behavior early enough.

The disclosed solutions apply to both direct and indirect V2V (sidelink) communication and uplink/downlink communication.

A basic idea of the invention is the introduction of soft admission control and explicit notification schemes for next available QoS bearer information to UE, during bearer establishment in the following cases: Initial attach (Connection Establishment); Dedicated bearer establishment (in RRC Connected state); Handover. Such a QoS negotiation may include the following messages: Early Notification for modifications of already established Bearers; Reply with a proposals of next available QoS Bearer or List (List of QCI/Priorities); Accept one of proposed Bearers that is described in the Request message.

The solution presented in this disclosure provides the following advantages: Latency can be reduced by reducing the message interaction between the group of vehicles and the network for the RRC establishment of new radio bearers. Consequently, this also reduces the signaling overhead. Explicit notification provided by the network to the group of vehicles about the change in QoS class due to sudden change in radio condition enables smooth vehicle transition to increase/decrease the distance between them before the actual modification of radio bearer. Continuous service provision reduces the service drop rate. The impact of QoS change can be reduced, especially for critical services. Reliability and availability of the future services of connected cars can be increased, due to early notifications of network QoS features, increasing the end-to-end system performance.

The disclosed solution provides additional information on available bearers in the bearer setup and maintenance processes to ease and speed up the connection establishment. Explicit notification schemes for next available QoS bearer information to UE are introduced, in particular during bearer establishment in the following cases: Initial attach (Connection Establishment), Dedicated bearer establishment (in RRC Connected state), Handover. The disclosed solution presents a new method for proactive signaling information exchange, including explicit notification of next available QoS bearer from the network, based on network conditions for the requests received by the vehicles/UEs in the case of a) Early Notification for modifications of already established Bearers; b) Reply with proposals of next available QoS Bearer or List (List of QCI/Priorities); and c) Accept one of proposed Bearers that is described in the Request message.

The disclosed solution presents an extended signaling to support soft bearer request from the vehicle/UE by providing the list/range of QoS classes that can support the target V2X Service. The disclosed solution presents use of periodic or event-triggered reporting by the vehicles or the Intelligent Transportation System (ITS) Server and assessing current network conditions.

In the following, Radio Access Networks (RANs) and Radio Admission Control (RAC) are described with respect to Quality of Service (QoS) requirements. The Radio Admission Control (RAC) algorithm admits or rejects bearer requests for new radio bearers. Admission Control (AC) is not standardized which means LTE Radio Access Network (RANs) will run different AC algorithms. The algorithm in contention situation triggers Radio Bearer Control (RBC) in which case the allocation happens on the basis of the Allocation and Retention Priority (ARP) parameters present along with the bearer request. Each dedicated bearer request contains QoS parameter like ARP, QCI, MBR, GBR etc. ARP contains 3 Mandatory fields: Priority Level, Pre-Emption Capability, Pre-Emption Vulnerability. Priority Level-Range is from 1 to 15 (where 1 is the highest priority). Pre-Emption Capability contains the following conditions: "Shall not trigger pre-emption": cannot preempt other bearers during resource congestion; and "May trigger preemption": can trigger preemption of other bearers during resource congestion. Pre-Emption Vulnerability contains the following conditions: "Not pre-emptable": This bearer cannot be pre-emptable by other bearers; and "Pre-emptable": This bearer can be released during resource congestion by other bearers. Dynamic QoS modification in an established bearer is possible in LTE with BS—modify eps bearer context request. In current systems only hard decisions related to pre-emption are provided, i.e. V-UE does not have extra degree of freedom in negotiating the QoS which is required so that to avoid over provisioning of resources or a rejection. An explicit notification of network conditions is missing.

The solution described in this disclosure presents soft admission control to introduce extra degree of freedom in negotiating the QoS and different notification schemes to enable a faster "negotiation" between a UE (or a group of them) and the Radio Access Network (RAN (BS) or Core Network (CN) entities (e.g., MME in LTE, AMF in 5G)) to establish vehicle-to-vehicle (V2V) radio bearers, whenever the Admission Control is triggered during scenarios such as Connection establishment, New Service/bearer establishment, Handover etc.

In order to describe the invention in detail, the following terms, abbreviations and notations will be used:

AF: Application Function
AMF: Access and Mobility Function
AS: Access stratum
CN: Core Network
CN-C: Core Network Control Plane
CN-F: Core Network Function
DRB: Dedicated Radio Bearer
ITS: Intelligent Transportation Systems
KPI: Key Performance Indicator
MME: Mobility Management Entity
QoS: Quality of Service
RAN: Radio Access Network
RRC: Radio Resource Control
TS: Technical Specification
UE: User Equipment

According to a first aspect, the invention relates to a mobile device, in particular a vehicle, wherein the mobile device comprises: a processor, configured to: receive a notification from a network entity, in particular a base station, wherein the notification comprises information about available Quality of Service, QoS, and transmit a confirmation message to the network entity informing the network entity about an acceptance of the notified QoS.

By using such a mobile device or UE, e.g. a vehicle, a faster "negotiation" between the mobile device (or a group of them) and the Radio Access Network (RAN (BS) or Core Network (CN) entities (e.g., MME in LTE, AMF in 5G)) can be enabled. Hence, vehicle-to-vehicle (V2V) radio bearers can be established whenever the Admission Control is triggered, e.g. during scenarios such as Connection establishment, New Service/bearer establishment, Handover etc. This results in faster and safe communication between mobile devices.

In an exemplary implementation form of the mobile device, the mobile device is configured to send a notification message to indicate to an application the available QoS.

This provides the advantage that the application running on the mobile device has all necessary information for ensuring safe communication.

In an exemplary implementation form of the mobile device, the mobile device is configured to receive from an application a notification on a selected QoS.

The notification will allow the V2X application in the vehicles to modify their driving behavior early enough.

In an exemplary implementation form of the mobile device, the processor is configured to receive the notification during an initial attachment, a dedicated bearer establishment or a handover phase of a bearer establishment, in particular radio bearer.

This provides the advantage that latency can be reduced by reducing the message interaction between the group of vehicles and the network for the RRC establishment of new radio bearers. Consequently, this also reduces the signaling overhead.

In an exemplary implementation form of the mobile device, the processor is configured to transmit a connection request message to the network entity, the connection request message comprising a specific QoS class, wherein the QoS class is a specific QoS level from a set and/or list of QoS levels.

This provides the advantage that the network is informed about specific requirements such as specific QoS classes required by the mobile device.

In an exemplary implementation form of the mobile device, the connection request message comprises a list of candidate QoS classes; and in particular the notification comprises at least one QoS class from the list of candidate QoS classes.

This provides the advantage that the network has the flexibility to choose between the QoS classes from the list.

In an exemplary implementation form of the mobile device, the notification comprises information about available resources supporting another QoS class, in particular a next available QoS class, in particular if the available resources do not support the specific QoS class.

This provides the advantage that the mobile device is informed about alternative QoS classes and can check if one of these QoS classed may fulfill its requirements. This provides more flexibility for system design.

In an exemplary implementation form of the mobile device, the information about available QoS within the notification comprises a list of available QoS classes and in particular mapping of these QoS classes to available resources.

This provides the advantage that the mobile device is informed about available resources and can react by selecting one of these resources.

In an exemplary implementation form of the mobile device, the notification from the network entity is received periodically or event-triggered, in particular triggered by a request of the mobile device.

This provides the advantage that flexible actions can be implemented.

In an exemplary implementation form of the mobile device, the processor is configured to periodically report information, in particular location, mobility information, radio conditions, application status of the mobile device.

This provides the advantage that the network can collect all necessary information and make them available to other devices in the network for improving communication.

According to a second aspect, the invention relates to an application server, wherein the application server comprises: a processor, configured to: receive a notification from a network entity, in particular a base station, wherein the notification comprises information about available Quality of Service, QoS, and transmit a confirmation message to the network entity informing the network entity about an acceptance of the notified QoS.

By using such an application server, a faster "negotiation" between the mobile device (or a group of them) and the Radio Access Network (RAN (BS) or Core Network (CN) entities (e.g., MME in LTE, AMF in 5G)) can be enabled. Hence, vehicle-to-vehicle (V2V) radio bearers can be established whenever the Admission Control is triggered, e.g. during scenarios such as Connection establishment, New Service/bearer establishment, Handover etc. This results in faster and safe communication between mobile devices.

In an exemplary implementation form of the application server, the application server is configured to send a notification message to indicate to an application the available QoS.

This provides the advantage that the application running on the application server has all necessary information for ensuring safe communication.

In an exemplary implementation form of the application server, the application server is configured to receive from an application a notification on a selected QoS.

The notification will allow the V2X application in the vehicles to modify their driving behavior early enough.

In an exemplary implementation form of the application server, the processor is configured to receive the notification during an initial attachment, a dedicated bearer establishment or a handover phase of a bearer establishment, in particular radio bearer.

This provides the advantage that latency can be reduced by reducing the message interaction between the group of vehicles and the network for the RRC establishment of new radio bearers. Consequently, this also reduces the signaling overhead.

In an exemplary implementation form of the application server, the processor is configured to transmit a connection request message to the network entity, the connection request message comprising a specific QoS class, wherein the QoS class is a specific QoS level from a set and/or list of QoS levels.

This provides the advantage that the network is informed about specific requirements such as specific QoS classes required by the mobile device.

In an exemplary implementation form of the application server, the connection request message comprises a list of candidate QoS classes; and in particular the notification comprises at least one QoS class from the list of candidate QoS classes.

This provides the advantage that the network has the flexibility to choose between the QoS classes from the list.

In an exemplary implementation form of the application server, the notification comprises information about available resources supporting another QoS class, in particular a next available QoS class, in particular if the available resources do not support the specific QoS class.

This provides the advantage that the application server is informed about alternative QoS classes and can check if one of these QoS classed may fulfill its requirements. This provides more flexibility for system design.

In an exemplary implementation form of the application server, the information about available QoS within the notification comprises a list of available QoS classes and in particular mapping of these QoS classes to available resources.

This provides the advantage that the application server is informed about available resources and can react by selecting one of these resources.

In an exemplary implementation form of the application server, the notification from the network entity is received periodically or event-triggered, in particular triggered by a request of the mobile device.

This provides the advantage that flexible actions can be implemented.

In an exemplary implementation form of the application server, the processor is configured to periodically report information, in particular location, mobility information, radio conditions, application status of the mobile device.

This provides the advantage that the network can collect all necessary information and make them available to other devices in the network for improving communication.

According to a third aspect, the invention relates to a network entity, comprising: a network entity controller, configured to: transmit a notification to a mobile device, in particular a vehicle, or an application server, wherein the notification comprises information about available Quality of Service, QoS, and receive a confirmation message from the mobile device or the application server informing about an acceptance of the notified QoS.

By using such a network entity, a faster "negotiation" between the mobile device (or a group of them) and the network entity, e.g. the Radio Access Network (RAN (BS) or Core Network (CN) entities (e.g., MME in LTE, AMF in 5G)) can be enabled. Hence, vehicle-to-vehicle (V2V) radio bearers can be established whenever the Admission Control is triggered, e.g. during scenarios such as Connection establishment, New Service/bearer establishment, Handover etc. This results in faster and safe communication between mobile devices.

In an exemplary implementation form of the network entity, the network entity controller is configured to transmit the notification upon request and/or pro-actively, in particular based on a prediction of a change in radio conditions.

This provides a high degree of flexibility in system design.

In an exemplary implementation form of the network entity, the network entity controller is configured to allocate resources related to a specific QoS to the mobile device or the application server upon acceptance of the notified QoS.

This provides the advantage that the mobile device is informed about available resources and can influence resource allocation by the network.

In an exemplary implementation form of the network entity, the network entity controller is configured: to transmit the notification to a group of vehicles or an application server, and to allocate the resources related to the specific

QoS to the group of vehicles if the network entity controller receives respective confirmation messages from all vehicles of the group of vehicles.

This will increase the reliability of the system, allowing the group of vehicles to be notified (feedback) early enough for a modification of a bearer. The V2X application in the vehicles will be allowed to modify their driving behavior early enough.

In an exemplary implementation form of the network entity, the network entity controller is configured to monitor the QoS of an established vehicle-to-everything, V2X, service.

This provides the advantage that a real-time QoS is available at the network entity.

According to a fourth aspect, the invention relates to a method for negotiating a Quality of Service, QoS, with a mobile device or an application server, the method comprising: receiving a notification from a network entity, in particular a base station, wherein the notification comprises information about available Quality of Service, QoS; and transmitting a confirmation message to the network entity informing the network entity about an acceptance of the notified QoS.

By using such a method, a faster "negotiation" between the mobile device (or a group of them) and the network entities can be enabled. Hence, vehicle-to-vehicle (V2V) radio bearers can be established whenever the Admission Control is triggered, e.g. during scenarios such as Connection establishment, New Service/bearer establishment, Handover etc. This results in faster and safe communication between mobile devices.

According to a fifth aspect, the invention relates to an application for the mobile device or for the application server according to the first or second aspect of the invention, wherein the application is configured to transmit a request to a mobile device, in particular a vehicle or an application server, wherein the request comprises information about required Quality of Service, QoS, wherein the application is configured to receive a confirmation message about an acceptance of the notified QoS from the mobile device.

This provides the advantage that applications running on the mobile device and/or application server can setup and dynamically modify the QoS bearers in a cooperative manner, considering network conditions and impact on driving behavior. For instance, a platooning application can modify the distance among platoon vehicles according to the QoS that the network can support for the communication among the members of the platoon at the specific period of time. The higher the QoS that the network can provide the denser the platoon can be.

In an exemplary implementation form of the application, the application is configured to receive a notification message that indicates an available QoS.

This provides the advantage that the application can optimally control the vehicles, e.g. distance between the members of the platoon based on the information from the notification message.

In an exemplary implementation form of the application, the application is configured to select the available QoS and, in particular, confirm the selection to the mobile device and/or to the application server.

The available QoS can be a single QoS or a list of different QoS-classes. Using a flexible design of QoS classes improves safety.

In an exemplary implementation form of the application, the application is configured to receive a single available QoS or a list of available QoS from a mobile device, in particular a vehicle, or from an application server; and the application is configured to transmit a response to the mobile device or the application server to approve the single available QoS or to select one QoS from the list of available QoS.

This provides the advantage that the application has the flexibility to choose between the QoS classes from the list.

In an exemplary implementation form of the application, the application is configured to transmit the request based on information about a target communication service of the mobile device.

This provides the advantage that the application can be tailored according to specific requirements.

In an exemplary implementation form of the application, the target communication service is related to a group of vehicles.

This provides the advantage that various traffic scenarios such as platooning, advanced driving, cooperative perception, etc. can be safely implemented.

In an exemplary implementation form of the application, the target communication service comprises a vehicle-to-everything, V2X, service, in particular one of the services: platooning, cooperative collision avoidance, cooperative sensing.

This provides the advantage that the application can be flexibly applied for different applications.

In an exemplary implementation form of the application, the request comprises a list of candidate QoS.

This provides the advantage that the application can select from the list of candidate QoS.

In the following, relevant aspects of the invention are highlighted:

A method for explicit notification of QoS available from the Base Station to the vehicles during connection establishment.

In the method the signaling is extended to support flexible connection request from the vehicle to the network by providing the range (or list) of QoS that could support the target V2X Service.

In the method early notification messages are sent from the Base Station to the vehicles about next available QoS class (based on some predictions and forecasting) for established bearers, to help vehicles to modify their driving behaviour early enough, based on the QoS class that could be supported (proactive signaling).

New signaling information is introduced about explicit notification of next available QoS bearer information from the Base Station to the Vehicles during bearer establishment: Extend messages in the context of a) Initial attach (RRC Idle to RRC Connected State), d) new Dedicated bearer establishment (MME is involved), c) handover (Explicit notification on next available QoS bearer information between Base Stations).

Extend signaling to support soft bearer request from the vehicle to the network by providing the range (or list) of QoS classes that could support the target V2X Service: Extend Vehicles'-initiated messages in the case of initial attach, new dedicated bearer establishment, or handover; In the case of handover a new type of information is proposed to be added in the measurement report together the List of (candidate) QoS level that the UE provides to the Base Station in the context of handover event and forwarded also to target Base Stations; Extend MBMS messages to activate bearers and respective RAN messages in the case of a V2X application server-initiated services requests.

Early notification messages are introduced from the Base Station to the vehicles about next available QoS class (based on some predictions and forecasting) for established bearers, to help vehicles to modify their driving behavior early enough, based on the QoS class that can be supported: Periodic or event triggered update notification messages can be provided by the Base Stations or any other RAN entity; Periodic or event-triggered reporting by the vehicles (or an ITS Server) to facilitate the notification messages.

BRIEF DESCRIPTION OF THE DRAWINGS

Further embodiments of the invention will be described with respect to the following figures, in which:

FIG. **1** shows a schematic diagram illustrating a vehicle **100**, e.g. a car, with V2X communication system **102** and Intelligent Transportation System (ITS) **101**;

FIG. **2** shows a schematic diagram illustrating two scenarios of the V2X enabled distance control feature: a) short distance **210** between the cars **201**, **202** and b) large distance **211** between the cars **201**, **202**;

FIG. **3** shows a schematic diagram illustrating an exemplary message sequence chart **300** for explicit notification of next available QoS Bearer in Initial Attachment according to the disclosure;

FIG. **4** shows a schematic diagram illustrating an exemplary message sequence chart **400** according to a second option for explicit notification of next available QoS Bearer in Initial Attachment according to the disclosure;

FIG. **5** shows a schematic diagram illustrating an exemplary message sequence chart **500** for explicit notification of next available QoS Bearer in New dedicated Bearer Establishment (vehicle is in RRC Connected state) according to the disclosure;

FIG. **6** shows a schematic diagram illustrating an exemplary message sequence chart **600** for explicit notification of next available QoS Bearer in Handover according to the disclosure;

FIG. **7** shows a schematic diagram illustrating an exemplary message sequence chart **700** for Soft Bearer Request in Initial Attachment according to the disclosure;

FIG. **8** shows a schematic diagram illustrating an exemplary message sequence chart **800** for Soft Bearer Request in New dedicated Bearer Establishment (vehicle is in RRC Connected state) according to the disclosure;

FIG. **9** shows a schematic diagram illustrating an exemplary message sequence chart **900** for Soft Bearer Request in Handover according to the disclosure;

FIG. **10** shows a schematic diagram illustrating an exemplary message sequence chart **1000** for Soft Bearer Request when V2X application server initiated services requests (MBMS case) according to the disclosure;

FIG. **11** shows a schematic diagram **1100** illustrating interfaces of the V2X application server according to the disclosure;

FIG. **12** shows a schematic diagram illustrating an exemplary message sequence chart **1200** for early notification for "Update of Established Bearers" according to the disclosure;

FIG. **13** shows a block diagram illustrating an exemplary mobile device **1300** (or application server or vehicle) negotiating QoS with a network entity according to the disclosure;

FIG. **14** shows a block diagram illustrating an exemplary network entity **1400** negotiating QoS with a mobile device or an application server according to the disclosure;

FIG. **15** shows a block diagram illustrating an exemplary application **1500** for requesting a required QoS according to the disclosure; and

FIG. **16** shows a schematic diagram illustrating an exemplary method **1600** for negotiating QoS according to the disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

In the following detailed description, reference is made to the accompanying drawings, which form a part thereof, and in which is shown by way of illustration specific aspects in which the disclosure may be practiced. It is understood that other aspects may be utilized and structural or logical changes may be made without departing from the scope of the present disclosure. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present disclosure is defined by the appended claims.

It is understood that comments made in connection with a described method may also hold true for a corresponding device or system configured to perform the method and vice versa. For example, if a specific method step is described, a corresponding device may include a unit to perform the described method step, even if such unit is not explicitly described or illustrated in the figures. Further, it is understood that the features of the various exemplary aspects described herein may be combined with each other, unless specifically noted otherwise.

The methods and devices described herein may also be implemented in wireless communication networks based on mobile communication standards similar to, e.g., LTE, in particular 4.5G, 5G and beyond. The methods and devices described herein may also be implemented in wireless communication networks, in particular communication networks similar to WiFi communication standards according to IEEE 802.11. The described devices may include integrated circuits and/or passives and may be manufactured according to various technologies. For example, the circuits may be designed as logic integrated circuits, analog integrated circuits, mixed signal integrated circuits, optical circuits, memory circuits and/or integrated passives.

The devices described herein may be configured to transmit and/or receive radio signals. Radio signals may be or may include radio frequency signals radiated by a radio transmitting device (or radio transmitter or sender) with a radio frequency lying in a range of about 3 kHz to 300 GHz.

The devices and systems described herein may include processors, memories and transceivers, i.e. transmitters and/or receivers. In the following description, the term "processor" describes any device that can be utilized for processing specific tasks (or blocks or steps). A processor can be a single processor or a multi-core processor or can include a set of processors or can include means for processing. A processor can process software or firmware or applications etc.

In the following, base stations and User Equipments are described. Examples of a base station may include access nodes, evolved NodeBs (eNBs), gNBs, NodeBs, master eNBs (MeNBs), secondary eNBs (SeNBs), remote radio heads and access points.

FIG. **1** shows a schematic diagram illustrating a vehicle **100**, e.g. a car. The vehicle comprises a V2X communication system **102** and an Intelligent Transportation System (ITS) **101**. The functionalities of both systems are described in the following.

FIG. **2** shows a schematic diagram illustrating two scenarios of the V2X enabled distance control feature: a) short

distance **210** between the cars **201**, **202** and b) large distance **211** between the cars **201**, **202**.

The network and vehicles/UEs can setup and dynamically modify the QoS bearers in a cooperative manner, considering network conditions and impact on driving behavior. For instance, a platooning application can modify the distance among platoon vehicles (e.g. vehicles **201**, **202** shown in FIG. **2**), according to the QoS that the network can support for the communication among the members of the platoon at the specific period of time. The higher the QoS that the network can provide the denser the platoon can be. In the upper scenario of FIG. **2** the distance **210** among the vehicles **201**, **202** that form the platoon is shorter while in the lower scenario of FIG. **2** the distance **211** among the vehicles **201**, **202** that form the platoon is larger.

FIG. **3** shows a schematic diagram illustrating an exemplary message sequence chart **300** for explicit notification of next available QoS Bearer in Initial Attachment according to the disclosure.

FIG. **3** illustrates the message sequence for a new method for proactive signaling information exchange, including explicit notification of next available QoS bearer information between BS **320** and UE **310**, e.g. vehicle **100** or **201**, **202** as shown in FIGS. **1** and **2**, during bearer establishment in-case of initial attach and handover. In Random establishment **301**, a random access preamble **302** is transmitted from UE **310** to Base Station **320**. BS **320** answers with Random Access Response **303**. In RRC Connection Establishment **304**, message RRC Connection Request **305** including Establishment cause and other parameters is transmitted from UE **310** to Base Station **320**. BS **320** performs admission control **306** and answers with RRC Connection Setup **307** indicating next available supported QoS class. Then UE **310** answers BS **320** with RRC Connection Setup Complete **308** and BS **320** transmits Service Request **309** to CN-F (Core network function) **330**, an entity of the network.

The Establishment cause describes the requested Service and consequently the required QoS. This is used by the Admission Control **306** to identify the requested resources.

In case that the BS **320** cannot support the initial request by the vehicle **310** for the requested QoS Class, then based on Admission Control **306** outcomes the BS **320** informs the UE **310** about next available QoS class that can be used to support the specific V2X Service. The Vehicle **310** will assess whether the available QoS class can be used to support the target V2X Service.

FIG. **4** shows a schematic diagram illustrating an exemplary message sequence chart **400** according to a second option for explicit notification of next available QoS Bearer in Initial Attachment according to the disclosure. In this second option an additional RRC connection update **401**, **402** is exchanged by UE **310** and BS **320**.

In Random establishment **301**, a random access preamble **302** is transmitted from UE **310** to Base Station **320**. BS **320** answers with Random Access Response **303**. In RRC Connection Establishment **304**, message RRC Connection Request **305** including Establishment cause and other parameters is transmitted from UE **310** to Base Station **320**. BS **320** performs admission control **306**. Depending on the outcome of admission control **306** an RRC Connection Update **401** is transmitted from BS **320** to UE **310** which processes the update and transmits RRC Connection Update Complete **402** to BS **320**. Then BS **320** transmits RRC Connection Setup **307** to UE **310** indicating next available supported QoS class. The UE **310** answers BS **320** with RRC Connection Setup Complete **308** and BS **320** transmits Service Request **309** to CN-F (Core network function) **330**, an entity of the network.

FIG. **5** shows a schematic diagram illustrating an exemplary message sequence chart **500** for explicit notification of next available QoS Bearer in New dedicated Bearer Establishment (vehicle is in RRC Connected state) according to the disclosure. In this scenario, the network proactively provides a list of alternatives for available QoS classes.

The message sequence chart **500** starts with the vehicle **310** in connection mode **501**. UE **310** transmits a NAS Service Request **502** to BS **320**. BS **320** forwards the NAS Service Request **503** to CN-F **330**. CN-F **330** transmits NAS Context Setup Request **504** to BS **320** which performs admission control **306**. Then BS **320** transmits RRC Connection Reconfiguration **506** indicating Next available supported QoS class to UE **310**. UE **310** answers BS **320** with RRC Connection Reconfiguration Complete **507** and BS **320** transmits NAS Context Setup Response **508** to CN-F **330**.

The BS **320**, based on Admission Control **306** outcomes, provides to the UE **310** the list of QoS classes (one or more) that can be allocated/guaranteed (e.g., 25 ms delay, 1% Packet loss, . . .) to the specific service, based on existing conditions. UL (control plane) resources are allocated to the vehicle **310** for fast response. The Vehicle **310**, considering that some V2X Services can be implemented using different degrees of KPIs, selects the appropriate QoS class and informs the BS **320**.

The BS **320**, having as an input the required V2X service and the QoS classes that can support the specific V2X service, selects the next available QoS class that can support V2X service, considering the network availability and network conditions. The next available supported QoS Class is provided as an input to the "RRC Connection Reconfiguration" message **506**. The Vehicle **310** checks whether the proposed "next available supported QoS Classes" can be used. In case that it is accepted then the UE **310** replies with the complete message **507**. Otherwise the request **506** is rejected.

FIG. **6** shows a schematic diagram illustrating an exemplary message sequence chart **600** for explicit notification of next available QoS Bearer in Handover according to the disclosure. The scenario describes an explicit notification on next available QoS bearer information between Base Stations, i.e. source BS **320** and target BS **321**.

The message sequence chart **600** starts with the vehicle **310** in connection mode **501**. UE **310** transmits a UE measurement report **602** to a source BS, e.g. BS **320** shown in FIGS. **4** and **5**. Source BS **320** performs a handover decision **603** and transmits Handover request to target BS **321**. Target BS **321** performs admission control **306** and transmits Handover Request Acknowledgement message **606** to source BS **320**. Then source BS **320** transmits Handover command **607** to UE to initiate a handover at the UE **310**. The source BS **320** detaches from old cell and initiates synchronization with new cell **608**. UE **310** transmits Handover Confirm message **609** to target BS **321** which starts delivering buffered packets to target eNodeB **610**.

FIG. **7** shows a schematic diagram illustrating an exemplary message sequence chart **700** for Soft Bearer Request in Initial Attachment according to the disclosure. The scenario describes Soft Bearer Request. UE **310** provides a range of QCI request for the BS **320** to decide, based on the admission control algorithm and BS **320** responds with the best one. A new signaling information about the possible group

of QoS request as part of soft radio bearer request for radio admission control during initial attach procedure and handover is presented.

The random access preamble **302** is transmitted from UE **310** to Base Station **320**. BS **320** answers with Random Access Response **303**. In RRC Connection Establishment **304**, message RRC Connection Request **305** including Establishment cause as described above with respect to FIG. **3** and list of candidate QoS levels and other parameters is transmitted from UE **310** to Base Station **320**. BS **320** performs admission control **306** and answers with RRC Connection Setup **307** indicating supported QoS class for the list of candidate QoS levels. Then UE **310** answers BS **320** with RRC Connection Setup Complete **308** and BS **320** transmits Service Request **309** to CN-F (Core network function) **330**.

FIG. **8** shows a schematic diagram illustrating an exemplary message sequence chart **800** for Soft Bearer Request in New dedicated Bearer Establishment (vehicle is in RRC Connected state) according to the disclosure.

UE **310** transmits a NAS Service Request **502** to BS **320**. BS **320** forwards the NAS Service Request **503** to CN-F **330**. CN-F **330** transmits NAS Context Setup Request **504** to BS **320** which performs admission control **306**. Then BS **320** transmits RRC Connection Reconfiguration **506** indicating supported QoS class to UE **310**. UE **310** answers BS **320** with RRC Connection Reconfiguration Complete **507** and BS **320** transmits NAS Context Setup Response **508** to CN-F **330**.

The Vehicle **310** includes in the "Service Request" **502** the list of QoS levels that can support the target V2X Service. The same information is added in the "Context Setup Request" message **504**. The BS **320**, having as an input the required V2X service and the QoS classes that can support the specific V2X service, selects the QoS class that can maximize the benefit for the UE **310**, considering the network availability and network conditions. The selected QoS Class is provided as an input to the "RRC Connection Reconfiguration" message **506**.

FIG. **9** shows a schematic diagram illustrating an exemplary message sequence chart **900** for Soft Bearer Request in Handover according to the disclosure. The scenario is similar to the scenario of FIG. **6**. The source BS **320** however informs UE **310** before transmitting Handover Request to target BS **321**.

The message sequence chart **900** starts with the vehicle **310** in connected mode **501**. UE **310** transmits a UE measurement report **602** to the source BS, e.g. BS **320** shown in FIGS. **4** and **5**. Source BS **320** performs a handover decision **603**. Then source BS transmits Handover QoS Configuration Request message **901** to UE **310** and UE **320** answers source BS **320** with Handover QoS Configuration Response **902**. Then source BS **320** transmits Handover request **604** to target BS **321**. Target BS **321** performs admission control **306** and transmits Handover Request Acknowledgement message **606** to source BS **320**. Then source BS **320** transmits Handover command **607** to UE to initiate a handover at the UE **310**. The source BS **320** detaches from old cell and initiates synchronization with new cell **608**. UE **310** transmits Handover Confirm message **609** to target BS **321** which starts delivering buffered packets to target eNodeB **610**.

A new event type is introduced in the Measurement Report. This event will enable/trigger the Source eNB **320** to ask the Vehicle **310** to specify the pool of candidate QoS classes in the case that the neighboring cell becomes x dB better than the serving cell.

Alternatively, the Handover QoS Configuration Response message **902** can be sent just after the UE measurement report **602**; without the request **901** of the Source eNB **320**.

E-UTRAN Radio Access Bearer (eRABs) to be Setup List includes the selected QoS, class.

FIG. **10** shows a schematic diagram illustrating an exemplary message sequence chart **1000** for Soft Bearer Request when V2X application server **1014** initiated services requests (MBMS case) according to the disclosure.

In the scenario of FIG. **10**, the V2X application server **1014** initiates Activate MBMS Bearer Request **1001** by transmitting this message to BM-SC **1013**. BM-SC **1013** transmits Session Start Request message **1002** to MBMS S-GW **1012** which forwards it to MME **1011** which forwards it to E-UTRAN **1010**, e.g. BS **320**. E-UTRAN **1010** then performs RAN resources setup **1003** with UE **310**. After completing RAN resources setup **1003** E-UTRAN **1010** transmits Session Start Response message **1004** to MME **1011** which forwards it to MBMS S-GW **1012** which forwards it to BM-SC **1013**. BM-SC **1013** transmits response message **1005** to V2X application server **1014**.

There are several types of session-based V2X services (Platooning, Cooperative Collision Avoidance, Cooperative Sensing . . .) where a group of vehicles are involved. A notification from the group of involved vehicles is needed before the upgrade to a better QoS level or the downgrade to a lower QoS level, with the "Modify EPS Bearer Context Request" messages and the corresponding responses. This facilitates the vehicles (V2X applications) to modify accordingly and smoothly (group-wise) their driving behavior. The network informs the vehicles that are involved in a specific V2X service about the expected change in the QoS level. Based on the response of the group of vehicles involved in the specific V2X service (e.g., platooning) the network will proceed to the modification of the Bearers.

If the QoS upgrade is not needed or accepted by the involved vehicles (e.g., one of the vehicles in the platoon cannot reduce further the gap) then the Modify EPS Bearer will not be sent to the group of involved vehicles. If the QoS downgrade is not accepted then the release of the session will be requested (or any other application layer modification) to satisfy the QoS levels that network can provide. In any other case the Modify EPS Bearer Context Request message will be sent to all involved vehicles.

The Periodic Check of Resources is based on local radio information and also on periodic reportings from vehicles (e.g., location, application status etc). In the case that the MME **1011** is not involved then the Base Station **1010** can send the "Bearers Update Request" message and the bearers modification will take place by RRC-Reconfiguration.

FIG. **11** shows a schematic diagram **1100** illustrating interfaces of the V2X application server according to the disclosure. The scenario of Early Notification for Change of Established Bearers (QoS) is described in the following.

The MB2 reference point (BM-SC **1013**<→V2X App Server **1014**) allows the application to request to activate, deactivate, and modify an MBMS bearer. The V2X Application Server **1014** adds in the Activate MBMS Bearer Request message **1001** (as shown in FIG. **10**) the list of QoS levels that can support the target V2X Service. The same information is added in the "Session Start Request" message **1002** (as shown in FIG. **10**) that is sent to the E-UTRAN entities **1010** for the establishment of the radio MBMS Bearers. The selected QoS Class is provided to the V2X App Server **1014** in order to modify accordingly the (DL) transmissions from the V2X App Server **1014** to the Vehicles **310**.

FIG. **12** shows a schematic diagram illustrating an exemplary message sequence chart **1200** for early notification for "Update of Established Bearers" according to the disclosure.

BS **320** starts with periodic check of resources by transmitting Upgrade/Downgrade **1201** of QoS based on network and/or road conditions to CN-F **330**. CN-F **330** transmits Bearers Update Request message **1202** to both UEs **1210**, **1220**. One of UEs **1210**, **1220** may be vehicle **320**, e.g. **100**, **201**, **202**. These UEs **1210**, **1220** answer CN-F **330** with Bearers Update Response message **1203**. Then CN-F **330** checks responses for bearer update **1204** and transmits modify EPS bearer Context Request message **1205** to UEs **1210**, **1220** which answer CN-F **330** with Modify EPS Bearer Context Accept message **1206**.

In the case that there is no "List of (candidate) QoS level(s)" in the Activate MBMS Bearer Request message, then based on the (MBMS) Admission Control outcomes, the next available QoS class (or a list of them) can be proposed to the V2X App Server (via the "Session Start Response" and the "Activate MBMS Bearer Response" messages). The V2X App Server **1014** selects the QoS level that satisfied its application layer needs.

FIG. **13** shows a block diagram illustrating an exemplary mobile device **1300**, for example a vehicle, or an application server negotiating QoS with a network entity according to the disclosure. The general structure of the device **1300** shown in FIG. **13** is the same for a mobile device and for an application server. It includes a processor **1301** for processing mobile-device specific tasks or application server specific tasks. The functions of the mobile device **1300** and the application server **1300** according to the disclosure are described in the following. The mobile device **1300** can be a vehicle, e.g. a vehicle **100**, **201**, **202** as described above with respect to FIGS. **1** and **2**. The mobile device **1300** can be a user equipment (UE) **310** as described above with respect to FIGS. **3** to **12**, e.g. a user equipment **310** arranged in a vehicle **100**, **201**, **202** as described above with respect to FIGS. **1** and **2**.

The processor **1301** is configured to receive a notification **1302** from a network entity, e.g. a network entity **1400** as described below with respect to FIG. **14**. The network entity may be a base station, e.g. a base station **320**, **321** as described above with respect to FIGS. **3** to **12**. The notification **1302** comprises information about available Quality of Service, QoS, e.g. as described above with respect to FIGS. **3** to **12**. The processor **1301** is configured to transmit a confirmation message **1303** to the network entity **1400**, **320**, **321** informing the network entity about an acceptance of the notified QoS.

The mobile device **1300**, **310** or the application server **1300**, **1014** may send a notification message to indicate to an application the available QoS, e.g. to an application **1500** as described below with respect to FIG. **15**. The application **1500** may run on a mobile device **1300** or on an application server **1300**. The mobile device or the application server may receive from an application **1500** a notification on a selected QoS.

The processor **1301** may receive the notification **1302** during an initial attachment, a dedicated bearer establishment or a handover phase of a bearer establishment, in particular radio bearer, e.g. as described above with respect to FIGS. **3** to **12**. The processor **1301** may transmit a connection request message to the network entity **1400**. The connection request message may comprise a specific QoS class. The QoS class may be a specific QoS level from a set and/or list of QoS levels.

The connection request message may comprise a list of candidate QoS classes. The notification **1302** may for example comprise at least one QoS class from the list of candidate QoS classes. The notification **1302** may comprise information about available resources supporting another QoS class, in particular a next available QoS class, in particular if the available resources do not support the specific QoS class.

The information about available QoS within the notification **1302** may comprise a list of available QoS classes and in particular mapping of these QoS classes to available resources. The notification **1302** from the network entity may be received periodically or event-triggered, in particular triggered by a request of the mobile device **1300**, **310**, e.g. as described above with respect to FIGS. **3** to **12**. The processor **1301** may be configured to periodically report information, in particular location, mobility information, radio conditions, application status of the mobile device.

FIG. **14** shows a block diagram illustrating an exemplary network entity **1400** negotiating QoS with a mobile device or an application server according to the disclosure. The network entity **1400** may be for example a CN-F **330** as described above with respect to FIGS. **3** to **12**. The network entity **1400** includes a network entity controller **1401** for performing control tasks.

The network entity controller **1401** is configured to transmit a notification, e.g. a notification **1302** as described above with respect to FIG. **13**, to a mobile device **1300**, **310**, in particular a vehicle, or an application server **1300**, **1014**, e.g. as described above with respect to FIG. **13**. The notification **1302** comprises information about available Quality of Service, QoS. The network entity controller **1401** is configured to receive a confirmation message, e.g. a confirmation message **1303** as described above with respect to FIG. **13**, from the mobile device **1300**, **310** or the application server **1300**, **1014** informing about an acceptance of the notified QoS.

The mobile device **1300** can be a vehicle, e.g. a vehicle **100**, **201**, **202** as described above with respect to FIGS. **1** and **2**. The mobile device **1300** can be a user equipment (UE) **310** as described above with respect to FIGS. **3** to **12**, e.g. a user equipment **310** arranged in a vehicle **100**, **201**, **202** as described above with respect to FIGS. **1** and **2**.

The network entity controller **1401** may transmit the notification **1302** upon request and/or pro-actively, in particular based on a prediction of a change in radio conditions. The network entity controller **1401** may allocate resources related to a specific QoS to the mobile device **1300**, **310** or the application server **1300**, **1014** upon acceptance of the notified QoS.

The network entity controller **1401** may be configured to transmit the notification **1302** to a group of vehicles or an application server, e.g. as described above with respect to FIGS. **3** to **12**. The network entity controller **1401** may be configured to allocate the resources related to the specific QoS to the group of vehicles if the network entity controller **1401** receives respective confirmation messages **1303** from all vehicles of the group of vehicles, e.g. as described above with respect to FIGS. **3** to **12**. The network entity controller **1401** may be configured to monitor the QoS of an established vehicle-to-everything, V2X, service.

FIG. **15** shows a block diagram illustrating an exemplary application **1500** for requesting a required QoS according to the disclosure. The application may be a software program and/or function running on a mobile device or an application server, e.g. a mobile device **1300**, **310** described above with respect to FIGS. **3** to **14** or an application server **1300**, **1014**

described above with respect to FIGS. **3** to **14**. Alternatively, the application **1500** may be a hardware circuit or circuitry implementing the function of the application as described in this disclosure. The mobile device **1300** can be a vehicle, e.g. a vehicle **100**, **201**, **202** as described above with respect to FIGS. **1** and **2**. The mobile device **1300** can be a user equipment (UE) **310** as described above with respect to FIGS. **3** to **12**, e.g. a user equipment **310** arranged in a vehicle **100**, **201**, **202** as described above with respect to FIGS. **1** and **2**.

The application **1500** is configured to transmit a request **1502** to a mobile device **1300**, **310**, in particular a vehicle or an application server **1300**, **1014**. The request **1502** comprises information about required Quality of Service, QoS. The application **1500** is configured to receive a confirmation message **1503** about an acceptance of the notified QoS from the mobile device **1300**, **310** or the application server **1300**, **1014**, e.g. as described above with respect to FIGS. **3** to **14**.

The application **1500** may receive a notification message that indicates an available QoS, e.g. as described above with respect to FIGS. **3** to **14**. The application **1500** may select the available QoS and, in particular, confirm **1503** the selection to the mobile device **1300**, **310** and/or to the application server **1300**, **1014**, e.g. as described above with respect to FIGS. **3** to **14**.

The application **1500** may receive a single available QoS or a list of available QoS from a mobile device **1300**, **310**, in particular a vehicle, or from an application server **1300**, **1014**, e.g. as described above with respect to FIGS. **3** to **14**. The application **1500** may be configured to transmit a response to the mobile device **1300**, **310** or the application server **1300**, **1014** to approve the single available QoS or to select one QoS from the list of available QoS.

The application **1500** may transmit the request **1502** based on information about a target communication service of the mobile device **1300**, **310**. Such target communication service may be related to a group of vehicles, e.g. as described above with respect to FIGS. **1** to **14**. The target communication service may comprise a vehicle-to-everything, V2X, service, in particular one of the services: platooning, cooperative collision avoidance, cooperative sensing, e.g. as described above with respect to FIGS. **1** to **14**. The request may comprise a list of candidate QoS.

FIG. **16** shows a schematic diagram illustrating an exemplary method **1600** for negotiating QoS according to the disclosure. The method may be implemented on a mobile device or an application server, e.g. a mobile device **1300** or an application server **1300** as described above with respect to FIG. **13**. The mobile device **1300** can be a vehicle, e.g. a vehicle **100**, **201**, **202** as described above with respect to FIGS. **1** and **2**. The mobile device **1300** can be a user equipment (UE) **310** as described above with respect to FIGS. **3** to **12**, e.g. a user equipment **310** arranged in a vehicle **100**, **201**, **202** as described above with respect to FIGS. **1** and **2**. The application server **1300** can be a V2X application server **1014** as described above with respect to FIGS. **10** and **11**.

The method **1600** includes receiving **1601** a notification from a network entity **1400**, in particular a base station, wherein the notification comprises information about available Quality of Service, QoS, e.g. as described above with respect to FIG. **13**.

The method **1600** includes transmitting **1602** a confirmation message to the network entity **1400** informing the network entity **1400** about an acceptance of the notified QoS, e.g. as described above with respect to FIGS. **3** to **12**.

The presented solution is based on a unique signaling in the radio interface, N2 interface and Xn interfaces which involves exchange of new messages; messages that are already available are enhanced with new content as well. Additionally the interactions among the different network entities (user equipment, BSs, Mobility Management) involve unique messages exchanges and introduction of new network functions. All the afore-mentioned messages and entities are targeting standardization.

The present disclosure also supports a computer program product including computer executable code or computer executable instructions that, when executed, causes at least one computer to execute the performing and computing steps described herein, in particular the steps of the method described above. Such a computer program product may include a readable non-transitory storage medium storing program code thereon for use by a computer. The program code may perform the processing and computing steps described herein, in particular the method described above.

While a particular feature or aspect of the disclosure may have been disclosed with respect to only one of several implementations, such feature or aspect may be combined with one or more other features or aspects of the other implementations as may be desired and advantageous for any given or particular application. Furthermore, to the extent that the terms "include", "have", "with", or other variants thereof are used in either the detailed description or the claims, such terms are intended to be inclusive in a manner similar to the term "comprise". Also, the terms "exemplary", "for example" and "e.g." are merely meant as an example, rather than the best or optimal. The terms "coupled" and "connected", along with derivatives may have been used. It should be understood that these terms may have been used to indicate that two elements cooperate or interact with each other regardless whether they are in direct physical or electrical contact, or they are not in direct contact with each other.

Although specific aspects have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific aspects shown and described without departing from the scope of the present disclosure. This application is intended to cover any adaptations or variations of the specific aspects discussed herein.

Although the elements in the following claims are recited in a particular sequence with corresponding labeling, unless the claim recitations otherwise imply a particular sequence for implementing some or all of those elements, those elements are not necessarily intended to be limited to being implemented in that particular sequence.

Many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the above teachings. Of course, those skilled in the art readily recognize that there are numerous applications of the invention beyond those described herein. While the present invention has been described with reference to one or more particular embodiments, those skilled in the art recognize that many changes may be made thereto without departing from the scope of the present invention. It is therefore to be understood that within the scope of the appended claims and their equivalents, the invention may be practiced otherwise than as specifically described herein.

What is claimed is:

1. A mobile device or an application server comprising a processor configured to:

send to a network entity a request including a set of quality of service (QoS) classes at an application layer of the mobile device or the application server;

receive a notification from the network entity, wherein the notification comprises at least one QoS class best matching the set of the QoS classes,

wherein the at least one QoS class is associated with at least one bearer candidate as a next available bearer for the mobile device or the application server, and

wherein the notification is received during a bearer establishment;

determine whether the at least one QoS class satisfies QoS needs of the application layer; and

send a message to the network entity either accepting or rejecting the at least one QoS class.

2. The mobile device or the application server according to claim **1**, wherein the processor is configured to send an application notification to indicate, to an application, the at least one QoS class.

3. The mobile device or the application server according to claim **1**, wherein the processor is configured to receive from an application a notification on a selected QoS class.

4. The mobile device or the application server according to claim **1**, wherein the bearer establishment is a radio bearer establishment.

5. The mobile device or the application server according to according to claim **1**, wherein the processor is configured to send a connection request to the network entity.

6. The mobile device or the application server according to claim **5**, wherein the connection request comprises a set of candidate QoS classes, and wherein the notification comprises at least one QoS class from the set of the candidate QoS classes.

7. The mobile device or the application server according to claim **5**, wherein the notification comprises information about available resources supporting another QoS class.

8. The mobile device or the application server according to claim **1**, wherein at least one QoS class included in the notification is mapped to available resources.

9. The mobile device or the application server of according to claim **1**, wherein the notification from the network entity is received periodically or is event-triggered.

10. A network entity comprising a network entity controller configured to:

receive, from a mobile device or an application server, a request comprising a set of quality of service (QoS) classes at an application layer of the mobile device or the application server;

send a notification to the mobile device or the application server, wherein the notification comprises at least one QoS class best matching the set of QoS classes,

wherein the at least one QoS class is associated with at least one bearer candidate as a next available bearer for the mobile device or the application server, and

wherein the notification is sent during a bearer establishment; and

receive a message from the mobile device or application server either accepting or rejecting the at least one QoS class based on whether the at least one QoS class satisfies QoS needs of the application layer.

11. The network entity according to claim **10**, wherein the network entity controller is configured to send the notification upon request or pro-actively.

12. The network entity according to claim **10**, wherein the network entity controller is further configured to:

send the notification to a group of vehicles, comprising the mobile device, or the application server, and

allocate the resources related to the specific QoS to the group of vehicles based upon the network entity controller receiving respective confirmation messages from all vehicles of the group of vehicles.

13. A method for negotiating a quality of service (QoS) with a mobile device or an application server, the method comprising:

sending to a network entity a request including a set of QoS classes at an application layer of the mobile device or the application server;

receiving a notification from the network entity, wherein the notification comprises at least one QoS class best matching the set of QoS classes,

wherein the at least one QoS class is associated with at least one bearer candidate as a next available bearer for the mobile device or the application server, and

wherein the notification is received during a bearer establishment;

determining whether the at least one QoS class satisfies QoS needs of the application layer; and

sending a message to the network entity either accepting or rejecting the at least one QoS class.

14. A non-transitory computer readable medium comprising instructions that, when executed by a processor, cause the processor to provides at least the following operations:

send to a network entity a request including a set of quality of service (QoS) classes at an application layer of a mobile device or an application server;

receive a notification from the network entity during a bearer establishment, wherein the notification comprises at least one QoS class best matching the set of the QoS classes,

wherein the at least one QoS class is associated with at least one bearer candidate as a next available bearer for the mobile device or the application server;

and

determine whether the at least one QoS class satisfies QoS needs of the application layer; and

send a message to the network entity either accepting or rejecting the at least one QoS class.

15. The non-transitory computer readable medium according to claim **14**, including instructions that, when executed, cause the processor to provide the following further operations:

select the available QoS and confirm the selection to the mobile device or to the application server.

16. The non-transitory computer readable medium according to claim **14**, including instructions that, when executed by the processor, cause the processor to provide the following further operations:

receive a single available QoS or a set of available QoS from the mobile device or from the application server; and

send a response to the mobile device or the application server to approve the single available QoS or to select one QoS from the set of available QoS.

17. The non-transitory computer readable medium according to claim **14**, including instructions that, when executed, cause the processor to provide the following further operations:

send the candidate request based on information about a target communication service of the mobile device, wherein the target communication service is related to a group of vehicles.

18. A network entity comprising a processor, wherein the processor is configured to:

send to another network entity a request comprising a set of quality of service (QoS) classes and a radio resource control (RRC) context;

receive a notification from the another network entity during a bearer establishment, wherein the notification comprises a next available supported QoS class, and an admitted set of radio bearers,

wherein the next available supported QoS class is associated with a next available bearer for the network entity;

determine whether the next available supported QoS class satisfies QoS needs of the network entity; and

send a message to the another network entity either accepting or rejecting the at least one QoS class.

19. The network entity according to claim **18**, wherein at least one QoS class included in the notification is mapped to available resources.

20. The network entity according to claim **18**, wherein the notification is received periodically or is event-triggered.

* * * * *